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(pp. 61-65)

By I. L. Rogel'berg and E. S. Shpichinetskii

Plasticity of nickel containing small admixture of sulphur, and some questions of desulphuration of nickel at melting

Sulphur is one of the most harmful admixtures in nickel. Brittleness of nickel due to presence of sulphur is mentioned several times in the literature. According to the literature datum, 0.005% S makes nickel unforgeable (1-4). There are also reported other limits of a perceptible influence of the sulphur on the plasticity of nickel at high temperatures: 0.01% (5), 0.02% (6), 0.03% and 0.015% (7). There is also known the case of brittleness of nickel occurring as the result of gas corrosion in a sulphur-containing atmosphere (8-10). The authors of the present article found that also in a quantity smaller than 0.005% also lowers the plasticity of nickel at both high and room temperature (12). In connection with the fact that the experiments in this work (a) were carried out on nickel containing 0.1-0.2% O_2 (nickel for nonpassivated anodes) it was undoubtedly interesting to investigate the influence of small admixtures of sulphur (smaller than 0.005%) on the plasticity of nickel containing a small addition of carbon, because the latter is employed for deoxidation at the melting of nearly all sorts of nickel. The necessity of investigating this fact arises from the fact that right up to the present time there are still being published works in which the harmful influence of small quantities of sulphur are subjected to doubt (13).

In the first part of the present article there are reported the results of the investigation of the influence of sulphur on carbon-containing nickel and presented supplementary data on the plasticity of nickel with a small admixture of sulphur in presence of 0.1-0.3% O_2. The second part is devoted to the question of the desulphuration of the nickel at the melting and the influence of the deformation on the plastic characteristics.

The influence of the admixture of sulphur on the plasticity was determined on a large number of specimens of nickel containing 0.001-0.005% S, 0.01-0.2% C or 0.05-0.3% O2 and minimal quantities of other admixtures. The results of the chemical analyses of the individual meltings of these nickels are presented in table 1.

The specimens were investigated on stretching at room and high temperature. In the first case the experiments were carried out on annealed and hardened specimens. The results of the mechanical testing of typical specimens (figures 1-4) show that the presence of 0.002-0.005% S in a nickel containing oxygen or carbon sharply lowers its plasticity. A decrease in the plasticity of the nickel at room temperature occurs after the annealing (compare figures 2 and 4), and may be due to precipitation from the solid solution of brittle particles of nickel sulphide at the grain boundaries. Hardening at a temperature above 900deg brings the sulphur into the solid solution and thereby imparts plasticity to thenickel. In this case, if the nickel contains less than 0.002% S it is plastic at room temperature regardless of whether it has been subjected to hardening or annealing. The brittleness of nickel with a content of 0.002-0.005% S at 650-850deg and the good plasticity at higher temperatures may have a connection with the particular character of the variation in the solubility of sulphur in nickel in dependence on the temperature, which we have also discussed elsewhere (12).

It is conceivable that such a course of the curve of the solubility is characteristic not only of the system sulphur-nickel (state diagram with retrogressive solidus) but also of other systems of nickel with elements bringing about brittleness, for example, with lead, bismuth and others. Nickel containing less than 0.002% S is plastic at all temperatures up to 1200deg. Putting the minimal content of sulphur bringing about brittleness of thenickel at 0.002% may not be wholly precise, because the employed methods of analyzing the nickel for sulphur (14), including the good method of combustion, are not reliablee at contents of sulphur of 0.002% and less.

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Table 1

Chemical compositions of nickels containing oxygen, carbon and admixture of sulphur, (*

(1) name of specimen
- (a) nickel containing oxygen and less than 0.002% S**
- (b) nickel containing oxygen and more than 0.002% S**
- (c) nickel containing oxygen and less than 0.002% S***
- (d) nickel containing oxygen and more than 0.002% S***
- (e) nickel containing carbon and less than 0.002% S**
- (f) nickel containing carbon and more than 0.002% S**
- (g) nickel containing carbon and less than 0.002% S***

1	O_2	C	Mg	Si	Mn	Fe	Zn	Cu	S
a	0.25	0.002	a0.0013	0.003	a0.0013	0.024	a0.0010	0.014	0.0017
b	0.07	0.003	a0.0013	0.006	0.0034	0.051	a0.0033	0.028	0.004
c	0.33	0.003	0.0018	0.018	a0.0013	0.042	a0.0010	0.020	0.0012
d	0.21	0.002	a0.0013	0.005	0.0020	0.032	0.0010	0.031	0.003
e	...	0.11	0.0115	0.010	*0.0013	0.025	0.0018	0.011	0.001
f	...	0.10	0.0013	0.004	a0.0013	0.022	a0.0010	0.003	0.004
g	...	0.11	a0.0013	0.007	a0.0013	0.020	a0.0010	0.030	0.0012
h	...	0.08	a0.0013	0.003	a0.0013	0.011	a0.0010	0.008	0.004

*Contents in specimen do not go above (%) Pb 0.0012; Sn 0.0011; Sb 0.0013; Bi 0.0010
** Specimen for testing at high temperature.
*** Specimen for testing at room temperature.
(a) less than

Despite heat brittleness nickel with 0.002-0.005% S rolls well in the hot, because hot rolling usually terminates at temperature about 900deg. Such rolling cannot be carried out on material when the rolling terminates at a lower temperature. In connection with the fact that our domestic nickels probably do not containing any admixtures which lower the plasticity other than nickel, it may be assumed that the frequently-observed hot-shortness (16-18) and cold-shortness (15) of nickel is in the vast majority of cases due to the sulphur present in it (b)

The high plasticity of nickels free of sulphur at temperatures up to 1200deg further confirms the view that monomorphous metals with a face-centered lattice do not have zones of heat brittleness if in the process of plastic deformation at high temperatures they do not interact with the surrounding medium and are free of harmful admixtures (19, 20).

Figure 1: Transverse contraction of nickel containing oxygen and sulphur in de-

dependence on temperature. (a) transverse contraction, %; (b) temperature of experiment, degC

Figure 2: Relative elongation of nickel containing oxygen and sulphur in dependence on annealing (hardening) temperature. (a) relative elongation, %; (b) annealing (hardening) temperature), degC; (c) hardening; (d) annealing; (e) hardening; (f) annealing

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Figure 3: Transverse contraction of nickel containing carbon and sulphur in dependence on temperature. (a) transverse contraction, %; (b) temperature of experiment, degC

Figure 4: Relative elongation of nickel containing carbon and sulphur in dependence on annealing (hardening) temperature. (a) relative elongatinn, %; (b) annealing (hardening) temperature, degC; (c) hardening; (d) annealing

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Besides deoxidation and degasification the nickel melt before pouring is subjected to desulphuration. This process does not give a complete removal of the sulphur but is carried out mainly for changing it into a different form which does not manifest itself on the plasticity of the nickel (c).

Judging by many references in the literature nickel can be desulphurized by additions of magnesium and manganese. Despite the fact that Merica and Waltenberg (1) already convincingly demonstrated a considerable superiority of magnesium as desulphuriser, in a number of sources (7, 11, 21) it is stated that the sulphur can be made harmless with either manganese or magnesium, or even with silicon (11). It should be noted that these assertions are sometimes far from being supported by experimental data. In connection with the fact that we found brittleness of nickel containing small admixtures of sulphur, intended for the production of semi-products by the domestic industry, it was interesting to investigate whether such small quantities of sulphur could be made harmless with the help of such plentiful desulphurisers as magnesium, calcium, and manganese; moreover, it was interesting to investigate the possibility of desulphurising small admixtures of sulphur with titanium, aluminum and beryllium.

Table 2

Chemical compositions of specimens of individual meltings,%

(1) specimen

(a) Ni plus C plus S plus 0.1 Mg
(b) Ni plus C plus S plus 0.1 Ce
(c) Ni plus C plus S plus 0.1 Si
(d) Ni plus C plus S plus 0.1 Mn
(e) Ni plus C plus S plus 0.1 Ti
(f) Ni plus C plus S plus 0.1 Al
(g) Ni plus C plus S plus 0.1 Be
(h) Ni plus C plus S plus 1 Ti
(i) Ni plus C plus S plus 1 Al
(j) Ni plus C plus S plus 1 Si
(k) Ni plus C plus S plus 1 Mn
(l) Ni plus C plus S plus 1 Mn plus 0.1 Mg

1	C	S	Mg	Mn	Si	Ce	Ti	Al
a	0.06	0.003	0.07	0.002	....	...	....	....
b	0.15	0.005	0.002	0.002	0.004	0.08	....	....
c	0.09	0.004	0.001	0.006	0.08	...	....	....
d	0.03	0.003	a0.001	0.08	0.01	...	....	....
e	0.05	0.005	a0.001	a0.001	0.03	...	0.04	....
f	0.07	0.003	0.002	0.001	0.016	...	....	0.09
g	0.15	0.006	0.003	0.012	0.03	...	....	....
h	0.06	0.006	a0.001	0.007	0.04	...	0.82	....
i	0.10	0.001	0.009	0.014	0.04	...	....	0.96
j	0.08	0.003	0.004	0.02	0.99	...	....	....
k	0.08	0.003	0.004	0.99	0.02	...	....	....
l	0.26	0.002	0.10	0.98	0.01	...	....	....

1	Be	Cu	Fe	Pb	Sn	Zn	Sb	Bi
a	....	0.008	0.05	a0.001	a0.001	a0.001	a0.001	a0.001
b	....	0.025	0.03	a0.001	a0.001	a0.001	a0.001	a0.001
c	....	0.041	0.024	a0.001	a0.001	a0.001	a0.001	a0.001
d	....	0.009	0.02	a0.001	a0.001	a0.001	a0.001	a0.001
e	....	0.002	0.025	a0.001	a0.001	a0.001	a0.001	a0.001
f	....	0.007	0.015	a0.001	a0.001	a0.001	a0.001	a0.001
g	0.06	0.02	0.006	a0.001	a0.001	a0.001	a0.001	a0.001
h	....	b0.031	0.04	a0.001	a0.001	a0.001	a0.001	a0.001
i	....	0.018	b0.038	a0.001	a0.001	a0.001	a0.001	a0.001
j	....	0.13	0.038	a0.001	a0.001	a0.001	a0.001	a0.001
k	....	0.037	0.026	a0.001	a0.001	a0.001	a0.001	a0.001
l	....	0.02[illegible]	0.0[illegible]	a0.001	a0.001	a0.001	a0.001	a0.001

(a) less then
(b) more then

There were prepared specimens of nickel containing 0.002-0.005% S, 0.1% C with additions of manganese, aluminum, titanium and silicon in quantities of 0.1 and 1.0% and additions of magnesium, calcium and beryllium in quantities of 0.03-0.1%.

The results of the chemical analyses of the individual meltings of these nickels are presented in table 2. The specimens were tested on stretching at various temperatures. The values of the transverse contraction in dependence on the temperature are presented in figures 5 and 6.

It was found that small admixtures of sulphur can be made harmless not only with such elements as magnesium, calcium and beryllium but also with aluminum or titanium if the latter are introduced into the nickel in large quantities.

Contrary to the widespread opinion, manganese did not desulphurise the nickel even when it was introduced into the melt in a quantity of 1%. The impossibility found in this investigation of desulphurizing small quantities of sulphur with manganese puts in doubt its employment as one of the elements of the "complex" deoxidizer" (C plus Si plus Mn plus Mg).

Summary

1. Nickel containing a small admixture of sulphur (0.002-0.005%) is brittle at room temperature in the annealed state and at temperature 650-850deg. Brittleness due to the presence of sulphur is characteristic of nickel which has not been deoxidised (contains oxygen) as well as ofnickel which has been deoxidized with carbon. Hardening a nickel containing sulphur at 900deg and higher makes it plastic at room temperature.

2. The brittleness of nickel preliminarily deoxidised with carbon due to the presence in it of a small admixture of sulphur (0.002-0.005%) can be eliminated by the addition of several hundredths of one percent of magnesium, calcium or beryllium or by a larger addition of titanium.

3. The brittleness of nickel due to the presence of a small admixture of sulphur (0.002-0.005%) is not eliminated by the addition to it of up to 1% Mn.

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Footnotes

(a) In the experimental part of the work there participated B. I. Puchkov and A. K. Agafonov.

(b) Here there is not considered the possibility of the arrival in the nickel at the melting of such admixtures as lead, since these cases are very rare.

(c) According here and below we shall regard as desulphurizers those additions to the nickel which paralyse the harmful influence of the sulphur on the plasticity.

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By K. P. Kalinin, M. P. Lyamina and M. S. Spiridonova

<u>Production of nickel strips of high purity.</u>

Developing industry is specifying constantly high specifications with respect to the quality of semiproducts of nonferrous metals and their alloys.

According to the requirements of the works of the radiotechnical industry the nickel strips and ribbons employed for the production of the details of electronic tubes must have a purity of 99.99% Ni, with a sum of admixtures not greater than 0.01%. Moreover, the strips and ribbons of nickel must contain a minimal quantity of gases and possess great density and plasticity.

The present industrial method of the production of nickel strips does not assure the production of nickel of the required purity. At the melting of cathodic nickel of purity 99.99% in the works furnace the nickel is enriched with various admixtures coming from the lining of the crucible, the employed fluxes and deoxidizers, and also contains large quantities of gases falling into the melt from the atmosphere. As a result of remelting of the nickel in the industrial furnace its purity is lowered and instead of Ni it contains in the better cases 99.80% and sometimes even less. The strips made from these ingots are unsuitable for making the details of electronic tubes.

The strips and ribbons made from sheets of cathodic nickel with employment of melting, although satisfying the requirements with respect to purity, do not find employment in the industry on account of their high contents of gases, which causes considerable brittleness and the formation of bubbles during the annealing of the details in an atmosphere of hydrogen.

The literature contains no information on the production of strips and ribbons of nickel of high purity.

At the Giprotsvetmetobrabotka Institute there were formulated two methods for the production of nickel strips of high purity based on the production of strips from nickel subjected to melting in the induction furnace under a vacuum (1954-

195[illegible]) and in the arc furnace under a vacuum (19[illegible]).

Induction melting of nickel under a vacuum

Induction melting and casting of ingots was carriedout with a vacuum arrangement consisting of a steel vacuum chamber of diameter 780 mm, height 980 mm. Inside the chamber there was mounted an inductor of diameter 300 mm, height 350 mm, having 11 turns. There were employed generators of power 50 and 100 kv.

The pump of type VN-1 has an output of 1100 liters/minute and assures a residual pressure in the chamber according to the rating plate of 5 . 10^{-3} mm Hg column.

The melting of the nickel was carriedout in a lined and caked magnesite crucible of inside diameter 200-210 mm, depth 300-350 mm. The material of the crucible consisted of a mixture of ground fused magnesite ([illegible]%), passing through a sieve with 3mm openings, and borax (3%). The magnesite contained up to 1% Si and up to 1.5% [illegible]. There were also tried for the lining of the crucible pure oxides of magnesium, aluminum and titanium.

Measurement of the residual pressure in the chamber of the furnace occurred with a shortened U-form mercury manometer; the temperature of the melt was measured with an optical pyrometer through an opening present in the lid of the chamber of the furnace.

The finished melt was poured via a funnel lined with magnesite powder mixed with fireclay into a shallow cast-iron mold with dimensions of the interior strips of 40x200x300mm. For decreasing the shrinkage in the mold there was employed a heat attachment.

In Figure [illegible] there is presented a schematic section of the chamber of the vacuum furnace.

For ascertaining the optimal technology of melting and casting of highgrade ingots there were investigated: the temperature and time necessary for degasification of the melt, the state of the vacuum, the velocity of pouring, the temperature of the [illegible] and [illegible], the degree of deoxidation of the metal, etc. A large number of experiments showed that highgrade ingots possessing a great density without surface defects were obtained with the following technological scheme.

Figure 1: Schematic section of induction vacuum furnace. (1) funnel; (2) mold; (3) inductor; [illegible] base.

The charge consisted of cathodic nickel of purity 99.99% in the form of square plates lying in the crucible in a pile, which prevented adhesion of the nickel to the crucible during the melting. For the deoxidation there was employed carbon in the form of a nickel-carbon alloy in a quantity of 0.06-0.1% of the weight of the charge. The alloy lay partly on the bottom of the crucible and partly on top of the charge. The degasification of the melt was carriedout for 30-40 minutes at 1500-1700deg and residual pressure 1-5 mm Hg column. The melting of the charge took 20 to 50 minutes, depending on the power of the generator. The pouring of the nickel under a vacuum into the mold was carried out at a temperature of the melt of 1700-1750deg via a funnel with a diameter of the opening of 6-7 mm, heated together with the mold to 300-400deg.

For decreasing the formation of cavities in the ingots there was employed a heat packing consisting of a mixture of magnesite and fireclay.

Carbon as the deoxidizer was employed for binding the oxygen present in the nickel in the form of nickel protoxide because cathodic nickel ofpurity 99.99% contains from 0.006 to 0.02% of O_2. Moreover, the nickel at the melting is enriched with oxygen from the oxidized drops remaining in the crucible from the preceding melting and also on account of the oxidation of the charge lying in the hot crucible and the air remaining in the chamber of the furnace.

Removal of the oxygen from the nickel under works conditions without employment of carbon as deoxidizer is impossible due to the fact that the elasticity of dissociation of nickel protoxide is very low (according to the datum of Rostovtsev it equals 0.4 mm Hg at 1727deg). No other deoxidizer can be employed in this case because they contaminate the metal.

The employment of carbon as the deoxidizer is connected with an unfavorable phenomenon consisting in that the surplus oxygen comes in contact with the walls [illegible] with the material of the crucible [illegible] and iron, as a result of which the [illegible] enriched with these elements. The quantity of nickel inthe nickel ingots as a result of the [illegible] does not go above 0.005%.

The nickel ingots produced with the vacuum arrangement at observance of the above-described conditions are distinguished by great density and plasticity and contain minimal quantities of gases and volatile admixtures (Figure 2).

Figure 2. Macrostructure of cast ingot of induction melting

According to the spectral analysis the nickel ingot contains 0.001-0.02% Si, 0.002-0.03% Fe, 0.001-0.006% Mg; according to the other admixtures the ingot does not differ from cathodic nickel of purity 99.99%.

The enrichment of the nickel with the enumerated admixtures at the melting in the induction vacuum furnace occurs on account of the lining of the crucible, the funnel and the mold. In the crucible, lined with aluminum oxide and titanium oxide the nickel is enriched with the elements entering into the composition of these oxides.

The quantity of gases in the cast ingots varied from 6 to 16 cc per 100 grams metal: oxygen from 0.002 to 0.005%; hydrogen from 0.0003 to 0.0007%.

The ingots of dimensions 40x200x300-350mm were subjected to hot rolling at 950-1050deg to thickness 16-20mm. After rolling the ingots were planed on both sides to a clean surface to depth 1-2 mm and again rolled at 950-1050deg to thickness to 4-5mm. The rolled strips were cut into cards, annealed in a reducing atmosphere of ammonia at 750-800deg, cleaned by brushing, and rolled in the cold state to the necessary thickness with intermediate annealing at 750-800deg.

The chemical compositions of the delivered strips according to TU214-57 are presented in the table.

(1) Mark of nickel strip

(2) nickel and cobalt (in sum not less than), %

(3) admixtures not greater than, %

1	2	3								
		Cu	Fe	[illegible]	[illegible]	Pb	Zn	Mn	Mg	C
NV	99.9	0.02	0.05	0.001	0.03	0.001	0.005	0.002	0.02	0.01
NV	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.001	0.005	0.002	0.01	0.01

Arc melting of nickel in a vacuum

The first experiments on arc melting of nickel of purity 99.99% were carried out in a vacuum arrangement consisting of a metal chamberof cylindrical form of inside diameter 210 mm and height 500mm and a copper water-cooled crystallizer of outside diameter 90mm, inside diameter 70-73mm and height 220 mounted in the chamber.

In figure 3 there is presented a schematic section of the arrangement. The generator has a power of 60 kv; the pump of type VN-1 has an output of 1100 liters/minute. Between the pump and the chamber there is provided a trap filled with liquid nitrogen for catching the water vapor and other admixtures.

The blanks (electrodes) were made from sheets of cathodic nickel of purity 99.99% by cutting strips of corresponding width and length; the rods were mounted by means of nickel rivets of diameter 40-45mm, length 300-350mm, weight 2.5-3 kg. One end was sharpened to a cone the other was mounted in a chuck with a thread.

In the beginning of the process of melting an arc forms between the point of the cone and the nickel plate lying on the bottom of the crystallizer. With advancing alignment of the crystallizer with the metal the stem with the attached electrode slowly descends in such a way that the arc is not interrupted. At the melting of the nickel of current strength was 1000-1200 amp at 30-40 volts. The melting process took 4[illegible] minutes at a residual pressure in the chamber of 0.01-0.005mm [illegible] which was measured with a [illegible] of type UTV-49.

Figure 3: Schematic section of arc arrangement. (1) stem; (2) crystallizer; (3) nickel plate; ([illegible]) [illegible]; ([illegible]) [illegible]; (6) electrode.

The cast ingots (weight 2-2.[illegible] kg, diameter 70 mm, height 70-80 mm), were [illegible] without internal defects. The surface of the ingots was rough. At some [illegible] small pits of depth up to [illegible] mm. Most of the ingots were hard [illegible] stuck to the walls. Lubrication of the wall of the crystallizer with powder of magnesium oxide in water eliminated adhesion of the ingot to it, and the surface of the ingots was satisfactory; lubrication with graphite and chroming of the surface of the crystallizer did not give positive results.

The cast ingots were hammered with the pneumatic hammer at 900-1000deg to [illegible] with a rectangular section, planed to a clean surface, and rolled at 900-1000deg to strips of thickness [illegible] mm. The cold treatment of the strips and ingots was the same as at the induction melting in a vacuum. The tests of the strips gave better results than with the nickel obtained by the vacuum induction melting.

For formulating the technology there were carried out experiments on ingots of diameter 200 mm, length 300-400mm, weight 70-80 kg. The ingots were made at a Moscow enterprise on an arrangement with a crystallizer of diameter 200 mm and height 1000 mm at a power of the generator of 300 kv. The duration of melting of these ingots was 35-40 minutes.

Below there presented a brief technological scheme of the casting of industrial ingots and the rolling of strips and ribbons from them.

1. Prepare from cathodic sheets of nickel of purity 99.99% consumptions electrodes of diameter 1[illegible]-1[illegible] mm, length 700-800 mm by cutting stripe of corresponding width and length and fastening them with nickel fasteners.

2. Melt the electrodes in the arc furnace with a water-cooled crystallizer of diameter 200 mm under a vacuum at a residual pressure of 2-3. 10^{-4} mm Hg and a current strength of 3000-400[illegible] amp. Duration of melting 35-40 minutes. A deoxidizer is not employed at arc melting.

3. Hot rolling of the ingots [illegible] at 950-1050deg, from diameter 200 mm to thickness [illegible]-50 mm.

4. [illegible] the strips on both sides to a clean surface to depth 1-2 mm.

[illegible] rolling of the [illegible] to thickness [illegible] mm.

The [illegible] and cold rolling of the strips to the corresponding thickness are carried out according to the technology employed for the strips of nickel melted in the vacuum induction furnace.

The [illegible] ingots were very dense, without pores or cavities, with a clean and smooth surface. The contents of admixtures in the experimental ingots according to the spectral analysis were as follows: 0.001-0.003% [illegible], 0.004-0.007% Fe, less than [illegible] other admixtures were the same as in nickel of purity [illegible] of oxygen less than 0.00[illegible] of hydrogen less than 0.0003%.

Characteristics of nickel melted in the induction and the arc vacuum furnace

The physical and mechanical characteristics of the nickel melted in the induction vacuum furnace and those of the nickel melted in the arc vacuum furnace, whether in the castings or in the processed form, are close to each other; it may be assumed that the hundredths of one percent of the admixtures in the nickel melted in the induction vacuum furnace do not manifest their characteristics appreciably.

In figure [illegible] there are presented the curves of the variation in the limit strength, the relative elongation, the contraction, and the growth of the grains of strips of nickel obtained at arc melting in dependence on the annealing temperature. In figure [illegible], there is presented the variation in the hardness, the limit strength and the relative elongation in dependence on the degree of deformation.

The density of the [illegible] nickel obtained at induction and arc melting is [illegible] grams/cc, in the deformed state [illegible] grams/cc, in the deformed and annealing state [illegible] grams/cc. The specific electroconductivity is 0.069-0.073 [illegible] thickness 0.[illegible] mm in the annealed state is 0.25-11.[illegible] mm.

Figure [illegible]. [illegible] variation [illegible], relative elongation, contraction and growth of grains of strips of nickel of arc melting in dependence on annealing temperature. [illegible] annealing temperature, degC; [illegible] size of grains, mm

Figure 5: Curves of variation in hardness, limit strength and relative elongation of strips of nickel [illegible] in dependence on degree of deformation. (a) [illegible] kg/sq [illegible] degree of deformation, %

[illegible]

1. [illegible] the nickel ingots obtained by arc melting under [illegible] with [illegible] minimal quantity of [illegible]. These ingots, in contrast to [illegible] do not possess admixtures coming from [illegible] funnel [illegible] mold.

2. [illegible] principal parameters of the casting in [illegible] furnaces of [illegible] ingots of weight [illegible] kg.

3. [illegible] from such nickel fully satisfy with [illegible] requirements of the radiotechnical industry; the works- [illegible] industrial adoption of this method in [illegible] induction vacuum furnace.

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(pp 51-55)

By I. D. Reznik, P. I. Voskresenskii and M. S. Kruglyakova, Gintsvetmet

Moisture of departing gases at caking or oxidized nickel ores

The content of oxygen in the departing gases of the agglomerating machine is great, sometimes going above 10-15%; this is due not only to the inleakage of air on the way from the grate of the agglomerating machine to the exhauster but also to the incomplete utilization of the oxygen of the air sucked through the caking charge. At the same time it has been found that with increasing quantity of sucked-through air the vertical velocity of caking increases, and the productivity of the agglomerating machine increases correspondingly.

The explanation of the disagreement between the direct dependence of the productivity of the agglomerating on the expenditure of air and its very incomplete utilization for the combustion of carbon will be found in A. M. Parfenov (1), who suggested that the vertical velocity of caking is determined by the velocity of drying of the moist layer of the charge lying below the burning layer. On this basis the sucked-through air must be regarded not only as a oxidizing agent but also as a heat-carrier, heating and drying the charge. An analogous view on the role of the gases in the process of caking has been stated by K. V. Vendeborn (2).

According to the heat balance calculated by I. D. Reznik (3), in the process of caking oxidized nickel ore there is expended on evaporation of the moisture of the charge up to 30% of all of the heat (this ore contains about 30% water).

For studying the mechanism of the removal of the moisture at caking there were undertaken experiments with air-dry oxidized nickel of the Batamshinsk deposits, from which there was screened out class plus6mm. The ore contained 39.3% SiO_2, 16.3% Fe, 8.3% MgO, 1.6%CaO, 5.7% Al_2O_3; the loss at heating was 13.7%. The salvage from the agglomerate of the preceding experiments was ground, and there was selected class minus5plus0.5mm. Of coke there was taken class minus3plus0.5mm.

The caking charge was prepared with the following weight ratios of the components:

air-dry ore......	100
salvage..........	25
coke.............	15
water, up to.....	15

The charge before caking was pelleted for 5 minutes in a drum of diameter 400 mm, which rotated at 21 rpm, and the pellets of diameter 3-5mm were poured out into an agglomerating bowl; the weight of the specimens was 1.8-2.0 kg; at the same time there were selected specimens for determining the moisture content.

The caking occurred in a bowl of diameter 100 mm, connected with a vacuum pump RMK-2. On the charge there was laid a layer of wood charcoal of weight 40 grams and a layer of sawdust for kindling.

The expenditure of air was measured with a pneumometric tube mounted in the measuring attachment. The scheme of the connections of the measuring arrangement is presented in figure 1.

In the process of caking the quantity of sucked-through air was maintained constant. The air was sucked through until cooling of the agglomerate; the solidified agglomerate was let fall three times onto a cast-iron plate from a height of 2 meters; the yield of class plus5mm characterized its stability.

The moisture content of the departing gases were measured with the transmitter with lithium chloride, as proposed by TsLA (4), and whose experimentation and practical designing were carried out by GipTsvetmet (P. I. Voskresenskii). The operating principle of this arrangement is as follows. With a special vacuum pump there is taken directly from the gas line a part of the departing gases, which goes into a thermostat with automatic regulation of the temperature. Constancy of the quantity of gas passing through the hygrometer is maintained with an automatic rheometer (6). The gas heated to 90deg enters the hygrometer, whose scheme is presented in figure 2. The apparatus has two chambers - A and B. In the chamber A is placed lithium chloride, which actively absorbs the moisture from the gas penetrating through the porous partition. The chamber B also has a porous partition. As a result of the absorption of water vapor from the gas in chamber A its pressure decreases in comparison with that of chamber B; the pressure difference is measured with a differential manometer. After graduation of the apparatus the pressure difference of the manometer enables the moisture content of the gas to be read off directly. The interia of the transmitter does not go above 60 seconds.

Figure 1: Scheme of laboratory agglomerating arrangement with measurement of the moisture content of the departing gases. (1) agglomerating bowl with charge; (2) bunker for dust; (3) vacuum pump RMK-2; (4) pneumometric tube with differential manometer for measuring quantity of air sucked through; (5) thermocouple with potentiometer for measuring temperaturein layer of charge; (6) thermocouple with potentiometer for measuring temperature of departing gases; (7) manometer for measuring rarefaction; (8) gas-intake tube; (9) heater; (10) transmitter determining moisture content of gas with automatic electroheater; (11) differential manometer of hygrometer; (12) transformer 220/12 volts; (13) automatic rheometer maintaining constancy of expenditure and temperature of gas; (14) vacuum pump

Figure 2: Transmitter for automatic determination of moisture content of gases. (A) chamber with absorber of lithium chloride; (B) vacuum chamber; (1) body of apparatus ; (2) glass with absorber; (3) cofer; (4) partition with microporous ebonite; (5) rubber lining; (6) connection; (7) connections for measuring pressure; housing for thermometer.

In the table there are presented the results of the experiment on caking charges with a constant thickness of the layer of 300 mm at various velocities of the sucking-through of air. A factual expenditure of air of 0.18 cubic meter per minute corresponded to a specific expenditure of 23.0 cubic meters per square meter per minute, and a factual expenditure of 0.30 cubic meter per minute to 38.3 cubic meters per cubic meter per minute of air.

In all of the experiments the vertical velocity of caking and the specific productivity was calculated according to the duration of the process from the moment of ignition until attainment of the maximal temperature of the departing gases.

Influence of expenditure of air on caking indices

(1) experiment No.

(2) charge

(a) moisture content, %
(b) put-in weight, kg/liter

(3) vertical velocity of caking, mm/minute

(4) output of agglomerate plus salvage referred to weight of charge, %

(5) specific productivity according to agglomerate plus salvage, metric tons per square meter per 24 hours.

(6) yield of class plus 5mm, %

(7) maximal rarefaction, mm water column

1	2		3	4	5	6	7
	a	b					
specific expenditure of air 23.0 per cubic meters per square meter per minute							
1	26.5	0.68	14.3	62.3	11.5	64.8	30
2	25.6	0.68	16.0	66.6	12.3	....	50
5	0	0.78	21.5	89.6	23.6	73.4	170
specific expenditure of air 38.3 per cubic meter per square meter per minute							
3	25.8	0.68	27.3	67.8	23.4	....	380
4	24.3	0.67	27.2	64.7	20.6	79.7	430
6	2.2	0.83	37.5	82.0	37.8	71.9	970

As can be seen from the table with increasing quantity of sucked-through air there increases in direct proportion the vertical velocity of caking at the usual moisture content of the charge, so that the process of caking runs to completion more quickly.

In figure 3, there is shown the variation in the temperature in the layer of charge and in the departing gases in the process of caking under the conditions of an expenditure of air of 23 cubic meters per square meter per minute. At a specific expenditure of air of 38.3 cubic meters per square meter per minute the character of the curves remains the same, but they reach their maxima in a shorter time.

Figure 3: Temperature in process of caking. Specific expenditure of air 23.0 cubic meters per square meter perminute; charge with optimal moisture content.

(1) temperature in layer at depth 40 meters from surface; (2) ditto, at depth 140 meters; (3) ditto, at depth 240 mm; (4) temperature of departing gases.

The measurements of the moisture contents of the gases in process of caking and the quantities of moisture determined on the basis of these measurements were in sufficiently close agreement with the contents of water in the caked ore specimens. This indicates a satisfactory precision of the indications of the hygrometer.

From a comparison of the variation in the moisture content and the temperature of the gases in the course of the process it can be seen that a sharp rise in the temperature corresponds to the beginning of the lowering of the moisture content of the gases, and the maximal temperature to the minimal moisture content. The dependence between the rarefaction and the temperature is blurred because of the small absolute value of the rarefaction. In the beginning of the process of caking the departing gases are saturated with water vapor; after ignition the gases condense and carry little moisture away with them; with increasing heating of the charge the temperature of the gases increases, which leads to a considerable increase in the quantity of moisture carried away with them. The moment of the beginning of lowering of the moisture content of the gases corresponds to cessation of condensation of the moisture in the lower layer of the charge and the beginning of its drying; at the same time there also begins a sharp increase in the temperature of the gases.

Figure 4: Temperature at process of caking. Specific expenditure of air 23.0 cubic meters per square meter per minute; tempering of charge. (1) temperature in layer at depth 40 mm from surface; (2) ditto, at depth 140 mm; (3) ditto, at depth 240 mm; (4) temperature of departing gases.

Also the vertical velocity of caking does not remain constant during the whole process of caking; in the beginning it is small, and it is only toward the end of the caking that it increases sharply.

During the experiment the quantity of sucked-through air was not varied.

For investigating the mutual connection between the variation in the gas-permeability of the charge in the process of caking and a supermoistened layer there were carried out experiments on caking preliminarily-tempered (experiment No. 5) and on preliminary-dried (experiment No. 6) pellets. The experiments showed that the absence of a supermoistened layer not only does not decrease the rarefaction in the process of caking, but, on the contrary, considerably increases the resistance at simultaneous extension of the region of high temperature over nearly the whole height of the charge. From figure 4, it can be seen that at caking the dry charge the temperature of the departing gases reached the maximal value more quickly than at the moist charge, but then remained at a high level for a long time, thereby complicating the determination of the moment of the end of the process of caking.

The flow resistance of the gas is directly proportional to the square of the velocity of the gas and the length of the path. In the layer the temperature goes to 1200deg, which increases the heating of the gas by 4-5 times, increases its velocity of passage through the zone of high temperature, and increases the resistance of the layer. At invariable section of the pores in the charge the resistance in this case must increase approximately 16-25 times, and at melted-shut pores the increase in the resistance must be still greater. Therefore the reason cause of the creation of a high rarefaction is not the presence of moisture but the high temperature developing in the zone of caking. With increasing extent of the zone of high temperature with advancing combustion there is lengthened the path of the gases in the hot layer, which also increases the resistance of the layer, thereby increasing therarefaction. When upperlayer of agglomerate begins to cool the zone of high temperature contracts and toward the end of the process the resistance decreases and also at the same time the rarefaction decreases.

Summary

1. For the first time there is employed the method of continuous measurement of the moisture content of the departing gases at agglomeration with the help of a transmitter filled with lithium chloride. This method enables investigation of

the role of the gas as a heat-carrier drying the charge, and can be recommended for investigating the process of caking.

2. As a result of experiments carried out it was found:

(a) In the beginning of the process of caking the departing gases are saturated with water vapor and have a low temperature. When the departing gas reaches 55-60deg its drying ability increases nearly 7 times; condensation of the moisture in the lower layer of the charge ceases and the layer begins to dry;

(b) The vertical velocity of caking in the beginning of the process was 3.3-5mm/minute; with increasing approach of the combustion to the grate it increased to 60 mm/minute.

(c) The average vertical velocity of caking is directly proportional with the quantity of sucked-through air. The cold departing gases with a temperature below 55-60deg slowly dry the moist layer and limit the velocity of the process;

(d) The presence of moisture in the charge prevents extension of the zone of high temperature, shortens the path of the gases in the range of high temperatur , and thereby decreases the resistance of the layer in the process of caking.

3. Theobtained experimental data indicate an important role of the moisture in the charge at the process of caking. At the caking of dry charges the resistance of the layer increases so greatly that under industrial conditions it would be necessary to provide much more powerful exhausters; moreover, the extension of the zone of high temperature over the whole height of the layer leads to incandescing of the agglomerate, which in its turn lowers the thermal efficiency of the agglomeration and brings about an increased expenditure of fuel.

The presence of moisture is necessary for lowering the resistance of the charge due to contraction of the zone of high temperature. The velocity of caking depends, besides on other factor not considered in the presence article, on the velocity of drying of the moist layer, and is directly proportional with the quantity of sucked-through air.

4. On the basis of the found role of the departing gases as a heat carrier there may be confirmed the following previously-made recommendations for increasing

the productivity of the agglomerating machine;:

(a) The quantity of air sucked through the charge can be considerably increased, even if it is not fully utilized as an oxidizing agent;

(b) Maintain the optimal moisture content of the charge established by the practice, and lower the moisture content in the presence of a considerable reserve of rarefaction created by the exhauster;

(c) Create conditions for heating the moist charge in such a way that the temperature of the departing gases at caking in each of the vacuum chambers is not lower than 55-60deg.

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(pp.44-50)

By Prof. D. I. Lisovskii, Mintsventsoloto

Process of sulphidisation of metals in main stage of processing oxidised nickel ores

The production of nickel in the Soviet Union began with the processing of the oxidized ores from the Ural deposits. As the sulphidiser at the melting of these ores there was employed gypsum, whose behavior in reductive media was first described in a work of V. Y. Mostovich (1).

From the valuable theoretical work of V. Y. Mostovich the metallurgists in the beginning drew the erroneous conclusion that in the shaft furnace, as well as in the laboratory boat, the reaction of the reduction of gypsum finishes before reaching 900deg. They overlooked other data of V. Y. Mostovich indicating the possibility of decomposition of the gypsum with silicic acid at temperature above 1000deg and of iron oxide above 1100deg. It was only later that it was noticed that the gypsum is not completely reduced in the furnace and that with its quantity it is impossible to regulate the composition and quantity of the matte obtained at the melting of oxidized ores. As the explanation of this phenomenon A.A. Tseidler (2) proposed a hypothesis according to which calcium sulphide interacts with oxides and silicates of nickel according to the reaction verified by D. I. Darkachev and A. A. Tseidler (3) and with reduced metallic nickel in presence of CO.

A. A. Tseidler studied the reducibility of various oxidized nickel ores, and found that at the extreme variation in the chemical and mineralogical composition of the specimens of ores the degree of reduction of the nickel and iron varies extremely. He though that at nickel melting in the shaft furnace there are created conditions assuring the formation of FeS, because there is nearly always a surplus of CaS.

A later investigation of S. Y. Kus'min and A. N. Vol'skii showed that the reaction of interaction of metallic iron and calcium sulphide at 700-1100deg proceeds only in an iron-oxidising atmosphere, at which first the iron is oxidised to FeO, and then the FeO reacts with CaS, with formation of FeS and CaO. The reaction is reversible, and its direction depends on the composition of the gas phase.

The direction of the reaction of FeO with CaS at 700-1100deg depends on the temperature and duration of the experiment, because there is formed a solid solution; with regard to the reaction of interaction of ferrous silicate and double iron-calcium silicates with CaS in the interval 700-1100deg, this reaction proceeds in the direction of formation of FeS.

At the melting of oxidised nickel ores in the shaft furnace with gypsum there are reached various degrees of metallisation of the matte, which probably depends on the various reducibilities of the ores.

Mattes of various chemical compositions are also obtained in the shaft furnace at the melting of converter slags, whose reducibility is relatively constant. Consequently the yield and composition of the crude matte cannot depend solely on the reducibilities of the oxides of iron, nickel and cobalt. A great role here is undoubtedly played by the gypsum, because the process of matte-formation is closely connected with the reactions of reduction, decomposition and interaction of the gypsum with the metal sulphides.

In view of the great importance of the behavior of gypsum in the shaft furnace we investigated the formation of calcium sulphide from natural technical gypsum in the presence of sulphides and oxides of metals and oxidised nickel ores.

Until recently it was an open question whether a loss in weight of the gypsum occurs at reduction as a result of the formation of clacium sulphide or other intermediate compounds which are fairly stable under the conditions of heating.

For elucidating this question there was studied the rational composition of the products of the reaction of reduction of gypsum with pure carbon monoxide and the synthetic gas of the shaft furnace in dependence on the time and temperature.

It was found that at the reduction of gypsum there is formed calcium sulphide through the intermediary of a compound of the type of $CaSO_3$. The content of this compound in the product of the reaction at [illegible] and [illegible]00deg increases sharply in the first hour from the beginning of the process, to reach 65-70%.

Since at the shaft melting there is mostly employed gypsum in large pieces (diameter up to 150 mm), there was studied its behavior in dependence of the size of the pieces at high temperatures in oxidative and reductive atmospheres.

Figure 1: Dependence of degree of reduction of technical gypsum with carbon monoxide on size of pieces at various temperatures. (a) degree of reduction,%; (b) weight of pieces, grams

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The investigation permits the conclusion that finely-ground technical-gypsum in a stream of air begins to decompose with evolution of sulphur gas only at 1200deg. At higher temperature (1300deg) decomposition of gypsum proceeds even much more slowly. At larger-sized pieces the gypsum begins to decompose at still higher temperatures.

It was found that with increasing temperature (figure 1) the velocity of reduction of technical gypsum increases, and with increasing piece size, regardless of the temperature, decreases. Consequently, the higher the temperature and the finer the grinding of the gypsum, the more completely and the more rapidly is it reduced with carbon monoxide.

Because the gypsum is incompletely reduced in the shaft furnace, calcium sulphide is present in all of the zones of the furnace, where it enters into interaction with the oxides (SiO_2, Al_2O_3, Fe_2O_3) of the ore, of the flux, of the slag and with the sulphides of the metals (Co, Ni, Fe, Ca), thereby exerting an influence of the yield of matte and the composition of the slag.

Figure 2: Degree of completeness of reactions between gypsum and sulphides in dependence on temperature. (a) degree of completeness of reaction,%; (b) in an atmosphere of nitrogen.

Figure 3: Dependence of degree of completeness of reaction between FeS and $CaSO_4$

on duration of heating. (a) degree of completeness of reaction,%; (b) time, minutes

The interaction of the gypsum with the oxides and sulphides can be represented in the form of the reactions:

$CaSO_4$ plus SiO_2 equals $CaO.SiO_2$ plus SO_2 plus $\frac{1}{2}O_2$;

$CaSO_4$ plus Fe_2O_3 equals $CaO.Fe_2O_3$ plus SO_2 plus $\frac{1}{2}O_2$ . . . etc;

FeS plus $3CaSO_4$ equals $3CaO$ plus FeO plus $4SO_2$;

CoS plus $3CaSO_4$ equals $3CaO$ plus CaO plus $4SO_2$. . . etc.

Depending on which of these reactions develops more successfully in the furnace there varies the degree of loss of sulphur with the gas, and therewith the yield of matte and the composition of the slag.

This partly explains why it is impossible in the industry to regulate the yield and composition of the matte with the quantity of gypsum charged into the furnace.

The sulphides of cobalt, nickel and iron, contrary to calcium sulphide, melt at comparatively low temperatures, with formation of the liquid phase. The latter penetrates through the pores into the depth of the pieces of gypsum and enters into reaction with formation on the surface of the pieces of a film of oxide, which prevents the calcium sulphate from interacting with the reductive gases of the furnace.

Investigation of the interaction of the gypsum with the sulphides showed that in an atmosphere of nitrogen already at 600deg the gypsum begins to react with nickel sulphides. The sulphides of the other metals (Co, Fe and Ca) begin to react with it at higher temperatures (820—860deg).

The curves of the dependence of the degree of completness of the reactions on the temperature (figure 2) show that the sulphides of cobalt and calcium interact with gypsum less energetically than iron sulphide. The least active reaction is that between gypsum and nickel sulphide, although it begins at a lower temperature than the other sulphides.

The process of interaction of FeS with $CaSO_4$ at 1000deg proceeds at a small velocity in the first [illegible] minutes (figure [illegible]). With passage of time the degree of completeness of this reaction reaches 95%, while under the same conditions in the cases of the sulphides of cobalt and nickel it is 53 and 25% respectively.

Figure 4: Variation in the rational composition of the products of heating an equimolecular mixture of CaS plus $3Fe_2O_3$ in an atmosphere of nitrogen in dependence on the temperature. (a) rational composition,% (b) loss of sulphur,%; (c) loss of [illegible]

Figure 5: Variation in the rational composition of products of heating an equimolecular mixture of CaS plus $3Fe_2O_3$ in an atmosphere of carbon monoxide in dependence on the temperature. (a) rational composition,%

Experiments showed that in a current of carbon monoxide, as also in a current of nitrogen, the gypsum begins to react with nickel sulphide at temperature about 600deg, with thq sulphides of cobalt and iron at temperature about 800deg, and with the oxides (SiO_2, Fe_2O_3, Al_2O_3) of the ore and with the slag in the interval 920-1000deg.

Investigation showed that in the shaft furnace there proceed to a smaller extent reactions in three different directions.

As a result of the reaction of the first direction (reduction and interaction of oxides with CaS) there are formed sulphides from oxides), and the quantity (yield) of matte is increased.

At the reaction of the second direction (interaction of gypsum with sulphides), on the contrary, the quantity (yield) of matte is decreased, and the sulphides of the matte are transformed to metal oxides (CoO, NiO, FeO).

And, finally, as a result of the reaction of the third direction ((interaction of gypsum with oxides (SiO_2, Fe_2O_3, Al_2O_3)) there is expended in the furnace the gypsum necessary for the sulphidisation.

For the regulation of the yield of matte it is important that the calcium sulphide forming shall not oxidise the iron oxide present in the ore and in the slag.

Investigation showed that in an atmosphere of nitrogen (figure 4) in the mixture of the reacting substance at temperature 820-850deg there proceed two reactions:

(1) CaS plus $4Fe_2O_3$ equals $CaSO_4$ plus 8FeO

(2) FeO plus CaS equals FeS plus CaO

Calcium sulphate at temperature above 820deg enters into interaction with iron sulphide according to the reaction

(3) $3CaSO_4$ plus FeS equals 3CaO plus FeO plus $4SO_2$,

besides which, FeS, at temperature above 800deg, according to the literature information, reacts with Fe_2O_3.

Wholly different is the course of the reaction in the same mixtures (CaS plus $4Fe_2O_3$ and CaS plus $4CaO.Fe_2O_3$) in a current of carbon monoxide (figure 5).

The above-presented reactions (1) and (2) also proceed in a reductive medium. However, the CaSO forming, due to its dispersity, is reduced by carbon monoxide at a greater velocity, as a result of which its content in the reacting mixture gradually decreases, wholly disappearing at 850deg.

The gypsum employed at shaft melting of oxidised nickel ores decomposes in the furnace with evolution of sulphur gas.

The interaction of sulphur gas with metal oxides in an oxidative atmosphere was investigated by V. V. Pechkovskii (4) (Permsk State University). He studied the influence of catalysts on the reaction SO_2 plus $\frac{1}{2}O_2$ goes reversibly into SO_3 and the transformation of various metaloxides to the corresponding sulphates in the temperature interval 400-1000deg.

V. V. Pechkovskii obtained the sulphates by acting sulphur gas on the powdery oxides (MgO, CaO, Fe_2O_3, Co_2O_3, Mn_2O_3). The three last oxides are according to his investigation catalytically active with respect to the reaction SO_2 plus $\frac{1}{2}O_2$ goes reversibly into SO_3 at temperature above 600deg.

However, in our opinion, the presence of carbon monoxide in the gas of the furnace excludes the possibility of formation of SO_3, and hence also of the metal sulphides. More plausible, therefore, is another mode of the sulphidisation, consisting in reduction of the metal oxides and the sulphur from the sulphur gas to elementary sulphur, followed by their interaction.

The reduction of the sulphur from the sulphur gas to elementary sulphur was the subject of an investigation of I. P. Yushkevich and V. A. Karshavin (5) and others. The process of reduction of Fe_2O_3 has also been well studied; in the agglomerate constituting the starting material for the melting, according to G. P. Korshunov (6), there is already present up to 1.5% metallic iron.

The formation of sulphides of iron from its oxides and sulphur gas in a reductive medium was studied by G. A. Shakov, S. S. Margolina and G. I. Gladkov (7), and later by A. V. Vanykov and the author of the present article. The sulphidisation of nickel and its oxidized compounds with vapor of elementary sulphur, with hydrogen sulphide and with sulphur gas was investigated by V. I. Smirnov and A. . . Arkhipov (8). The literature contains the data of D. M. Chizhikov and R. . Serebryanya (9) on the study of the interaction of the sulphates of iron, nickel and cobalt with elementary sulphur ((9). Finally, by V. A. Vanykov, A. V. Vanyukov and A. N. Rudrin there were carried out investigations on the sulphidisation of agglomerates of oxidized nickel ores with the furnace gas.

All of these works on the study of the interaction of gases with the components of the charge confirm in one degree or another the assumption of D.G.Novkov (11) on the possibility of formation of matte in the shaft furnace directly through the interaction of vapor of elementary sulphur with the reduced metal. However, it is impossible to agree with his assumption that until the moment of the formation in the furnace of CaS nearly all of the nickel is present in the metallic state, and that "sulphidisation in the furnace of the silicates of nickel and iron is impossible because they are not in sufficiently close contact with each other". In the actuality such a contact is present in the lower zones of the furnace.

[illegible] a certain role of the sulphur gas in the process of sulphidisation, it is impossible to deny the occurrence of the formation of matte via calcium sulphide. V. A. Smirnov (12), for example, thinks that it is the most plausible to attribute the [illegible] to the calcium sulphide.

In this connection there is of some interest the chemical and mineralogical investigations carried out by the Institute of Mintsvetmetzoloto of the charge at various horizons of the "frozen" shaft furnace melting oxidized nickel ores with gypsum, they confirmed the fundamental role of the calcium sulphide in the sulphidization and only some participation in this process of the sulphur present in the gas.

Parallel specimens of the components of the charge taken from the furnace at the same melting were studied by [illegible] nev, [illegible] Khusakin, [illegible] Lyumkis and L.L. Chermak (13). On the basis of their investigations they came to the conclusion that "the process of matte-formation (sulphidization and reduction) proceeds principally in the lower part of the furnace due to the interaction" of the elements of the charge in the liquid phase.

Because gypsum is an imperfect sulphidizer there has been increasingly recommended in recent years the replacement of gypsum with copper-free pyrites. Thus, D. G. Novikov (11) thinks that leaching of the sulphur from the pyrite at 700deg and its further oxidation creates favorable conditions for the sulphidization with elementary sulphur of the reduced nickel in the upper part of the furnace; at this there are decreased the expenditure of coke and the ferrite-formation. V. I. Beregovskii (14) recommends the replacement of gypsum with pyrites, because the latter do have the disadvantages of gypsum, and this replacement gives a considerable saving of coke. I. D. Reznik (15, 16) proposes carrying out the melting of oxidized nickel ore with pyrites to "multi-sulphur" poor matte for the purpose of lowering the loss of nickel with the dumped slag and decreasing the formation of ferronickel.

The literature also contains contradictory statements. L . L. Chermak and Y. K. Osipov (17) and A. V. Prishletsov (18) refer to the necessity of the employment of gypsum. The latter, on the basis of his experiments, thinks that in the case of the employment of gypsum at the melting of iron-containing nickel ore there forms only a small quantity of ferronickel, which is not disadvantageous at intensive melting.

V. [illegible] Smirnov and [illegible] ([illegible]) have studied the employment of gypsum and pyrites at the melting of converter slags. In the laboratory experiments a variation in the expenditure of gypsum from 17 to 25% of the weight of the slag did not appreciably increase the extraction of the metals or change the composition of the crude matte. Laboratory meltings showed that with increasing expenditure of gypsum - from 10 to 30% of the weight of the slag - the extraction of the cobalt increases smoothly and the content of the metal in the discarded slag decreases correspondingly. At melting with pyrites, however, the waste slag is received with higher contents of iron and cobalt than at melting with gypsum.

If there could be found a still better process for reduction of gypsum in the shaft furnace with formation of CaS, then melting with gypsum would be better than melting with pyrites, especially at the melting of ferruginous nickel ores and converter slags, because the calcium sulphide separates out iron, nickel and cobalt from the melt in the form of their sulphides, with formation of matte. Pyrites do not separate the iron from the slag into the matte, so that the slag remains more ferruginous, and hence also with higher contents of nickel and cobalt.

In view of the imperfection of the process of sulphidisation in the furnace V. A. Vanykov and A.V.Vanykov (20) proposed that pyrites be introduced into the charge at the agglomeration of the ores, on the assumption that this would increase the extraction of nickel in the process of shaft melting of the ore.

Of great importance to lowering the losses of metal is the metallisation of the matte, because the greater the metallisation is the smaller are the losses of nickel and cobalt with the slag.

For solving the problem of increasing the extraction of metals from oxidised nickel ores a group of coworkers of the Mintsvetmetzoloto Institute and the South-Ural-Nickel Combine is at present working onthe formulation of amethod for impoverishment of the slags and a method for sulphidisation of oxidised ores followed by flotation of the sulphides as proposed by V. A. Vanykov, A.V. Vanykov and

I. M. Yudina (21). The latter method was anticipated by the work of G.A.Shkhov (22) and the author of the present article on the study of the interactions of the oxides and silicates of nickel and cobalt with sulphidisation of the iron and cobalt in the solid phase.

An interesting work on extracting the cobalt from liquid converter slags by intermixing with ore matte was carried out by I. I. Chernak (23, 24), which enabled the South-Ural-Nickel Combine to organize the impoverishment of converter slags without the necessity of melting them in the shaft furnace.

Obviously the next step in the developments in this direction must be the impoverishment of the waste slags with various sulphidizers.

Metallurgical calculations carried out by A. A. Tsaidler (25) show that the slags can be impoverished by carrying out this process in an electroheated settling tank with the help of pyrites and coke.

The feasibility of the impoverments of slag with sulphidizers has also been reported by [illegible] Iguchis (26) and I. M. Bochkarev (27).

Experiments carried out by coworkers of the Mintsvetmetzoloto Institute in collaboration with workers of the South-Ural-Nickel Combine showed that preliminary preparation with calcium sulphide may be feasible in connection with the impoverishment of the waste slags outside of the furnace.

By the introduction of supplementary processes into the general technological scheme there can be improved the process of sulphidization metals in the main stages of the processing of oxidized nickel ores, thereby increasing the extraction of nickel and cobalt from the raw material.

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(pp 40-44)

By N. I. Gran, North-Nickel Combine

Enrichment of alloys of nickel and cobalt with iron by oxidative blowing on wüstite slag

At oxidative refining of metals and some other cases there are obtained metal-oxide admixtures for better separating them of the principal phases bound in silicates, that is, the oxidation process is carried out in the presence of silica because silicates are practically insoluble in metallic alloys and mattes. At this of great importance is also the lower melting temperatures of silicates compared with oxides.

The necessity of slagging the products of oxidation with silica is absent in those cases when theoxides forming are little soluble in the oxide phase and are sufficiently easy-melting.

The cobalt alloy obtained at the reductive melting of converter slags consists of iron, nickel, copper, cobalt and sulphur. The iron is the principal component of the alloy: its content reaches 70%. Due to the fact that the affinity of iron to oxygen is greater than that of the other metals, there exists the possibility of carrying out on the industrial scale the enrichment of the cobalt alloy by blowing it with air (1) with separation of iron in the form of silicate slag. At this the contents of copper, nickel and cobalt in the slag do not go above fractions of one percent, increasing with their increasing contents in the alloy.

Many investigations have shown that liquid iron does not mix with its liquid lower oxide - wüstite (2).

The presence of a region of stratification in the system iron-oxygen demonstrates in principle the possibility of separating the iron (in the form of wüstite) from the nobler metals by oxidative blowing of the melt with quartz flux.

Copper, analogously to iron, does not mix with its low oxides in liquid form. Therefore iron-copper alloys stratify with wüstite, or, more probably, with a solution of cuprous oxide in wüstite, at any content of copper in the alloy.

On the contrary, in the systems nickel-oxygen and cobalt-oxygen stratification of the metal and the protoxide does not occur. From this it follows that a high content of cobalt and nickel in an alloy with iron will adversely affect the stratification of the wüstite (more probably, a solution of protoxides of nickel and cobalt in wüstite) with the alloy.

Investigation of the equilibria between the alloy and the wüstite slag in the systems iron-cobalt-oxygen and iron-nickel--oxygen (3) showed that the presence in the alloy of up to 30% Co and up to 80% Ni does not yet worsen the strification (a). At this the wüstite slag contained up to 1.3% Co and up to 4% Ni.

Because in the binary system iron-sulphur and in the pseudobinary system wüstite-ironsulphide in the liquid state there is observed complete mutual solubility, therefore sulphur worsens the stratification of iron with wüstite. At a content of sulphur in the alloy of about 12% and temperature 1450deg stratification is not observed (4). In our case the presence of sulphur did not prevent fluxless blowing, because, firstly, the content of sulphur in the alloy did not go above 7%, and, secondly, during the blowing it decreased still further.

On the basis of the literature information it may be assumed that from the works cobalt alloys by fluxless oxidation a part of the iron canbe separated out in the form of wüstite slag, despite the presence in the alloy of nickel, cobalt and sulphur, which worsens the stratification.

Fluxless blowing of cobalt alloy, introduced into the industry at the North-Nickel Combine on the recommendation of the author, was carried out in a five-ton converter with lateral blast (five tuyeres of diameter 38 mm), lined with chromomagnesite. For heating the lining after reconditioning and heating the converter during shutdowns there was provided an oil burner of low pressure (Stal'proyekt type). Before beginning the blowing the opening for the oil jet was plugged with fireclay.

Figure 1: Variation in composition of slag during fluxless blowing of alloy.

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(a) ratio Fe : Co in alloy; (b) content of Fe in slag, %; (c) content of Co, Ni, Cu, S in slag, %

The cobalt alloy, taken from the electrofurnace with a content of 3-4% Co, was poured into the converterwith a ladle lined with chamotte or foam-chamotte. The blowing occurred without collection of the mass. The duration of the blowing was selected according to the content of cobalt to be obtained in the rich alloy. At the above-stated content of cobalt in the poor alloy it was usually 30-40 minutes. The temperature of the mass in the converter increased during the blowing, Sometimes going above 1500-1550deg, and for lowering it there was added scrap at the rate of 0.25-0.50 metric ton per thousand cubic meters blast. However, this quantity of scrap was insufficient for maintaining the temperature of the mass at a constant level.

The blowing process was interrupted 1-2 times for letting out the slag. A characteristic particularity occurring at fluxless blowing of the slag was its very low viscosity, which it retained nearly to its solidifying temperature. The end of the outflow of slag was determined by the "collapse"; the shine of a drop of alloy could be clearly seen on the background of the slag. After finishing the blowing the slag was poured off first. The end of the operation was verified with the rapid stylometer by determining the content of cobalt in the alloy.

The casting of the alloy to anodes occurring directly from the converter. The obtained alloy contained 7-8% Co, and in some cases up to 10%.

The variation on the composition of the cobalt alloys during its fluxless blowing at 1430-1440deg is presented in the table, and the variation in the composition of the slag coexisting with this alloy is shown in figure 1.

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(1) specimen No.

(a) starting alloy

(2) (Fe)/(Co)

(3) content of component, %

(a) Co
(b) Ni

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(c) Cu
(d) Fe
(e) S

1	2	3				
		a	b	c	d	e
a	9.55	5.81	27.7	12.0	56.1	1.30
1	9.15	5.85	26.1	12.6	53.6	1.16
2	8.15	6.25	28.0	....	50.9	1.07
3	7.22	6.60	30.1	14.1	47.6	0.94
4	6.19	7.04	32.2	15.1	43.6	0.86
5	4.37	8.12	37.8	17.6	35.4	0.73
6	3.42	8.72	41.1	19.0	29.8	0.69
7	2.56	9.30	44.8	20.6	23.8	....
8	1.50	10.38	50.2	23.1	15.5	0.61

Figure 2: Microstructure of alloy obtained at fluxless blowing. x165

On the abscissa axis there is plotted the ratio iron to cobalt, at which, even when there is no content of cobalt in the alloy, this ratio still determines the content of cobalt in the slag. As can be seen from the figure, the content of iron in the slag remains practically constant, above 70%. The contents of cobalt and nickel inthe slag increase with advancing oxidation, doing so particularly sharply when the ratio iron to cobalt goes down to 5. An analogous phenomenon was observed at the blowing of cobalt alloy with quartz flux.

The content of sulphur in the slag decreases in the course of the blowing. The content of copper in the slag varied in a peculiar manner; although, as can be seen from the figure, the content of copper in the alloy increased continuously, in the slag it at first decreased and again increased only toward the end of the blowing.

A specimen of the slag obtained at fluxless blowing of a cobalt alloy under works conditions was subjected to microscopic and roentgenostructural analysis for determining its substantial composition. The chemical composition of the slag was: 1.0% Co, 0.92% Ni, 1.33% Cu, 68.9% Fe, 0.55% S, 3.22% SiO_2. The presence in the slag of more than 3% SiO_2 (usually it is less than 1%), is due to the fact that there came into the converter besides the alloy also silicate slag from the electrofurnace.

In the photograph of the microstructure of the unetched specimen (figure 2), it can be seen that most of the area of the section is occupied by coarse rounded grains of wüstite (b), and that the intervals between its grains are filled with fayalite. Different is the composition of the slag: glass (darker fayalite) and sulphide (brighter wüstite), less easily distinguishable on the photograph. At cooling of the slag to room temperature, as the result of disintegration of the wüstite in it, there is disclosed (at great magnification) the presence of metallic iron and magnetite(the latter only after etching).

The primary magnetite, which should have separated out at the crystallization of the melt, was not found in the fluxless-blown slag.

The roentgenostructural analysis showed that the main component of the slag forming at the fluxless blowing of the cobalt alloy is a substance with a face-centered cubic lattice, whose average parameter equals 4.298 angstroms. Of all of the modifications of ironand its oxide a cubic syngony ofsuch a great parameter corresponds only to wüstite.

The yield of wüstite slag at blowing of the alloy is nearly 1½ times smaller than that of silicate slag, and the heat capacity of wüstite if 2 times smaller than that of fayalite. Because of this at the North-Nickel Combine the expenditure of oil for heating the converter at fluxless blowing is nearly twice lower than at blowing with flux (0.5-0.6 instead of 1.42 metric tons per metric ton rich anodes). Thanks to the hot operation of the converter at fluxless blowing there is facilitated the cleaning of the tuyeres and the general management of the process. As a result of this there has occurred an increase in the content of cobalt in the anodes from 6.50% at blowing with flux (average for 2½ years) to 7.35% at fluxless blowing (average also for the last 2½ years). Due to the increased content of cobalt in the anodes the productivity of the hydrometallurgical operation of the Combine has increased 11%, while the expenditure of sulphuric acid has decreased 12% and that of soda 16%.

While the described process of fluxless blowing was formulated and adopted preferably for the blowing of cobalt alloy, it can, in my opinion, also be applied to blowing for the purpose of enriching with iron the poor ferronickel obtained at the reductive melting of oxidized nickel ore.

Melting such ores with poor ferronickel, with possibly more complete reduction of the iron and nickel contained in the ore, enables bringing the loss of nickel and hence also of cobalt with the dumped slag to a minimum, thereby solving an important problem confronting the metallurgist: considerably to increase the extraction of these metals from the ore.

Fluxless oxidation of iron-nickel alloys, containing up to 80% Ni in the induction furnace showed that at 1502-1525deg the oxidized phase is a solution of nickel protoxide and wüstite. The content of iron in it is 74--77%, while the content of nickel protoxide depends on the composition of the ferronickel, and can be approximately found by the equation

(80) equals 0.76 ((Ni)/(Fe)).

The possible extractions of nickel, calculated from the experimental data in dependence on its content in poor and rich alloy are represented in figure 3.

Figure 3: Dependence of extraction of nickel on final ferronickel on content of nickel in starting and final ferronickel. (a) extraction of Ni in final ferronickel, %; (b) content of Ni in final ferronickel, %

Each of these curves shows the dependence of the extraction of nickel on the composition of the rich alloy at the given starting content the ein of nickel, which is indicated by the numerical values at the curves. The extractions were calculated on the basis of the condition that all of the slags forming at the blowing fromthe starting content ofnickel to any content thereof in the rich slag were poured off only once. This reservation is necessary because the extraction also depends on the number of decantations of the slag. With the help of the curves present in figure 3, it is easy to determine what will be the extraction of nickel in the alloy at any number of decantations of the slag. For example, it is desired to obtain from ferronickel with 3% ferronickel with 80% nickel. Assume that the slag is poured off at contents of nickel in the alloy of 10, 30, 80%. From the curves we find that the extraction of 3percentual in 10percentual ferronickel is 97% from 10percentual in 30percentual ferronickel, 97%, from 30percentual in 80percentual ferronickel 92%.

The sum of the extractions from 3percentual ferronickel in 80% will be

((97 x 97 x 92)/(100 x 100 x 100)) x 100 equals 86.5%.

Accordingly, from 3percentual ferronickel at a total of only three decantations of the slag during the blowing there can be obtained a ferronickel with a content of 80% Ni and an extractionof nickel of 86.5%, while at partial reduction of the iron and nickel from oxidized ores, according to the data of N. N. Dobrokyotov and A. A. Sigov (6), the extraction of nickel in 10percentual ferronickel is about 88% and in 20percentual only 56%. Consequently reductive melting of oxidized nickel ore, at reduction of all of the iron and nickel, in conjunction with fluxless blowing of the poor ferronickel obtained thereat, gives a higher extraction.

The employment of reductive melting of oxidized nickel ore with further fluxless blowing of the poor ferronickel solves incidentally also the problem of the extraction of the nickel fromthese ores. The processing of wüstite containing 70-85% Fe to pig iron or steel should not present difficulties. The employment of wüstite slag as ore for Martin melting would enable extraction of the iron without a supplementary expenditure of reducer.

In oxidized ores the nickel is always accompanied by cobalt. Oxidative blowing of poor ferronickel enables separation from the nickel not only the iron but also the cobalt. As can be seen from figure 1, intensive passage of cobalt into the slag beings when the ratio iron to cobalt in the blown alloy goes down to 5. The slag obtained from this moment of blowing is richer in cobalt, and can therefore be subjected to special processing for its extraction.

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(pp.35-39)

By G. I. Dobrokhotov and N. I. Omuchkina, Gipronikel

Autoclave leaching of cobalt products at the South-Ural-Nickel Combine

The present technological scheme of the processing of rich cobalt matte and anodic alloy at the South-Ural-Nickel Combine includes a number of pyro- and hydrometallurgical operations: remelting of the matte, bessemerization of the sulphide material to anodic alloy (1,2), pouring of the anodes, electrolytical dissolution of the alloy, dissolution of the obtained hydrates in sulphuric acid, purification of the solutions from iron and copper, etc. All of these operations are accompanied by the production of a large number of working materials and semiproducts, and in the end lead to solutions with a relatively low content of cobalt. Such solutions bring about the necessity of apparatuses of great capacity in the hydro-metallurgical department and increased expenditures on their further conversion. The whole technological scheme is complicated and tedious.

In the present article there are reported the results of the laboratory verification of a process of acidic autoclave leaching consisting in the treatment of aqueous pulps of the sulphides with oxygen under pressure (3). Such a treatment of the cobalt matte and the anodic alloy is accompanied by oxidation of the sulphides, and, in contrast to the present technology, leads directly to solutions of sulphates of nickel and cobalt.

The process is characterized by the following general reactions:

CoS plus $2O_2$ equals $CoSO_4$;

Ni_3S_2 plus $4O_2$ plus H_2SO_4 equals $3NiSO_4$ plus H_2;

FeS plus $2O_2$ equals $FeSO_4$;

$4FeSO_4$ plus O_2 plus $2H_2SO_4$ equals $2Fe_2(SO_4)_3$ plus $2H_2O$;

$Fe_2(SO_4)_3$ plus $4H_2O$ equals $3H_2SO_4$ plus $Fe_2O_3.H_2O$.

The investigations described below were carried out with a series of industrial materials whose names and compositions are presented in the table.

Composition of starting materials, %

(1) name of material

(a) anodic alloy
(b) cobalt matte

(2) component

(a) Ni
(b) Co
(c) Cu
(d) Fe
(e) S
(f) remainder

(3) (a)/(Ni plus Co plus Cu) . grams/atom

1	2						3
	a	b	c	d	e	f	
a	60.66	7.46	0.82	4.68	25.79	0.59	0.69
b	17.42	3.76	0.32	4	25.63	5.86	2.22

For carrying out the experiments the specimens were ground in the ball mill to size 71 microns.

The experiments on leaching under pressure of hydrogen were carried out in an autoclave of volume 3.0 liters with the agitator system of N.E.Vishnevskii (4) without a gasket. The driving of the agitator occurred by a rotor magnetically connected with the stator through a thin-walled screen of chromonickel steel. The presence of the highspeed agitator and of a diffuser directly the stream of pulp enabled intensive intermixing of the solution and its saturation with oxygen. Usually the autoclave was filled with the pulp to only 70-80% of its capacity. In this case the precise calculation of the intensity of the intermixing was impossible because of the unknown values of the viscosity and density of the forming gas-liquid mixture.

At complete filling of the autoclave with water the Reynolds number (Re) was 20,000-25,000.

All of the experiments on leaching were cyclic with registration of the pressure of the total gas mixture. The beginning of the introduction of oxygen

(O_2 of purity 96-98%) into the autoclave was simultaneous with the beginning of the heating, and this moment was taken as the beginning of the leaching. At 70-80deg there began energetic oxidation of the sulphides, as a result of which the temperature rapidly increased to that required by the regime of the process.

In the beginning the pressure of the oxygen was maintained low, which enabled a smoother and more manageable raising of the temperature; beginning in themiddle and continuing to the end of the experiment the autoclave was supplementarily heated with an electric heater connected with a contact galvanometer. The latter enabled maintenance of the selected temperature with a precision of plus or minus 1deg.

The acidity of the solutions was determined with the help of a glass electrode after cooling of the taken specimens to 25deg or their titration with employment of methylorange asindicator. In the latter case there was determined the total content of oxygen - free and partly bound in the ferrisulphate.

Leaching of anodic alloy: The anodic alloy is a rich product, which determines the small volume necessary for the leaching apparatus of high pressure. As can be seen from the table the content of sulphur in the alloy is insufficient for the formation of soluble sulphates. Consequently leaching of the alloy is possible only at the introduction of a supplementary quantity of sulphur in the form of sulphuric acid.

The results of the research experiments, carried out for determining the principal parameters and particulars of the process of leaching, are presented in figures 1 and 2. The experiments were carried out at temperature 115deg, total pressure of oxygen 5-20 atm, charge of alloy 300 grams, charge of solution of sulphuric acid of variable concentration 2.1 liters.

Figure 1: Influence of acidity of starting solution on composition of final solution at leaching of anodic alloy. Temperature 115deg; pressure of oxygen 10 atm. (a) acidity in grams/liter; (b) content of Ni, grams/liter; (c) content of Co, grams/liter; (d) content of Fe, grams/liter; (e) pH; (f) extraction of Ni, %; (g) Extraction of Co,%; (h) extractin of Fe,%; (i) hours

In figure 1 there is shown the variation in the composition of the solution at various additions of sulphuric acid. Rapid and effective dissolution of the sulphides is assured only at the proper acidity of the starting solution. At an initial content of sulphuric acid of 5 - 7 grams/liter the dissolution of the cobalt material proceeds at an average velocity of about 15-20 grams/liter nickel per hour, which, in the case of the production of strongly concentrated solutions, determines a duration of the process of leaching of 4-6 hours. Since a concentration of sulphuric acid of 57 grams/liter is insufficient for complete dissolution of all of the sulphides, in this case the process is followed by a partial hydrolytical purification of the solution. At acidities of 44 and 22 grams/liter there is observed a complete purification of the final solution from iron and copper, but the extractions of nickel and cobalt are small.

From figure 2, where there is shown the influence of the pressure of the oxygen, it can be seen that the dissolution of the sulphides and the oxidation of the ferrosulphate at the velocities employed in the practice are observed only at a pressure of 10 atm and higher. The optimal conditions of the process lie in the range of 10-15 atm.

Figure 2: Influence of pressure of oxygen on composition of solution at leaching of anodic alloy. Temperature 115deg; acidity of starting solution 87 grams/liter. (1) [illegible] (2) [illegible] atm; (3) [illegible] atm, [illegible] atm. (6) content of nickel, grams/liter; [illegible]

The results of the balance experiments are presented in figure 3. The starting solution contained 57 grams/liter sulphuric acid, the final solution 80-84 grams/liter nickel and about 10 grams/liter cobalt. In contrast to autoclave treatment of ore concentrates, leaching of the anodic material is not accompanied by the formation of sulphur alloy. Consequently a higher temperature manifests itself favorably on the results of the leaching. Under the conditions of the process at 115deg, pressure of the oxygen 110 atm, and duration of leaching 6 hour, there are extracted from the solution about 95% of the nickel, cobalt, copper and sulphur. When the temperature is raised to 135deg the extraction of these components from the solution increases to nearly 100deg. At 115deg such high indices can be attained only by lengthening the duration of the leaching to 8 hours.

Figure 3: Influence of temperature and duration of experiment on extraction of nickel, cobalt and sulphur from anodic alloy. Pressure of oxygen 10 atm; acidity of starting solution 87 grams/liter. (a) extraction,%; (b)hours

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At the selection of the optimal regime of leaching there must be taken into account a number of supplementary circumstances. It is known (5) that the chemical stability of chromonickel steel, the principal material of autoclaves and reactors, decreases rapidly with increasing temperature and acidity of the solution, but increases with increasing concentration of oxidizers, for example, ferrisulphate. Under the conditions of intermittent leaching with simultaneous charging of the starting materials the initial content of acid is great and ferrisulphate is absent in the solution; this requires the selection of a low temperature. The conditions of continuous leaching are more favorable, and the temperature of the process can be selected high.

Figure 4: Velocity of sedimentation of pulp of iron hydroxide obtained at autoclave leaching of mixture. (a) velocity of sedimentation, cm/hr; (b) H_2SO_4, grams/liter

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In figure 4 there are presented the results of the determination of the velocity of sedimentation of the pulp, evaluated indirectly by the filtrability of the sediment forming at various acidities of the solution. From the found data it follows that the optimal regime of the formation of iron hydroxide corresponds to a total content of sulphuric acid of 4-9 grams/liter. This concentration corresponds to a concentration of ferrisulphate in the solution of 0.5-1.0 gram/liter. From this it follows that the extraction of the iron from the sediment under the optimal conditions is about 90-95%.

<u>Leaching of matte:</u> By the adoption of leaching of cobalt matte several of

the operations are eliminated from the present scheme. However, in this case there occurs a great increase in the expenditure of oxygen and an increase in the capacity of the necessary high-pressure equipment.

The experiments on leaching the matte were carried with a charge of 600 grams of matte and 2.1 liters of solution of sulphuric acid of variable concentration. At this ratio the yield of iron cake (referred to dry product) was 420-440 grams, and there were assured the conditions for obtaining a final solution with a combined content of nickel and cobalt of about 60 grams/liter, and, at return of the washing water the concentration of the metals in the final solution was 75-85 grams/liter.

The experiments showed that oxidation of the sulphides does not occur in neutral and weakly-alkaline media. In acidic solutions oxidation occurs with formation of soluble sulphates and sulphur alloy. Some of the latter dissolves in the unreacted sulphides, thereby lowering the extraction of the metals in the solution.

The influence of the acidity of the starting solution on the extraction of the metals and the sulphur in the solution and in the alloy at 115deg and oxygen pressure 10 atm is shown in Figure 5. The increasing yield of sulphur alloy with increasing acidity in this case is explained by the preferable chemical interaction between the sulphides and the acids at relatively rapid oxidation of the sulphide ions to elementary sulphur. The thermodynamic analysis of this question showed that the oxidative-reductive potential of the reaction of sulphide ions to sulphate ions depends little on the concentration of the hydrogen sulphide. On the other hand, the potential of the reaction of oxidation of sulphide ions to elementary sulphur increases rapidly with decreasing content of hydrogen sulphide. Accordingly, increasingly energetic separation of hydrogen sulphide and attainment of a high concentration thereof increases the yield of elementary sulphur, while leaching the sulphides at a low content of H_2S favors the formation of sulphides. The concentration of H_2S can be lowered by increasing the intensity of mixing of liquid with gas or by increasing the oxygen pressure.

The optimal conditions of cyclic leaching of cobalt matte are as follows: temperature 115deg; oxygen pressure 10-15 atm; acidity of starting solution 5-10 grams/liter. In the solution there is extracted 95-98% Ni, 95-96% Co, 10-15% Fe and 55-65% S.

Figure 5: Influence of acidity of starting solution on distribution of nickel, cobalt, iron and sulphur at leaching of cobalt matte. Temperature 115deg; oxygen pressure 10 atm; duration of leaching 6 hours. (a) extraction; (b) solution; (c) alloy; (d) tails; (e) solution; (f) alloy; (g) tails; (h) alloy; (i) solution; (j) tails; (k) solution; (l) sulphur alloy; (m) tails

Here the strongly acidic solution contaminated with iron and the formation of the sulphur alloy prevent forcing of the process by raising the temperature, which is a serious disadvantage of the method of intermittent leaching. However, both of these difficulties are absent with the method of continuous leaching. Specifically, there exist the possibilities of adding bases for neutralizing the excess acidity, leaching at a low concentration of hydrogen sulphide, operating constant and steady temperature, etc.

Another variant of the optimal conditions consists in regulating the composition of the cobalt matte. In this case the contents in it of nickel, cobalt and sulphur are determined by calculation of the obtained solutions. This method is based on partial blowing of the matte in the converter, and can be carried out exclusively by autoclave treatment of the principal mass of iron sulphides.

Summary

1. The optimal conditions of intermittent leaching of cobalt matte are: temperature 115deg; oxygen pressure 10-15 atm; duration of operation 6-8 hours. In the solution there are extracted 95-98% Ni, 95-96% Co, 10-15% Fe and 55-65% S. The optimal conditions of leaching anodic alloy are: temperature 115-135deg, oxygen pressure 10 atm, duration of operation 4-8 hours. In the solution there are extracted 95-100% Ni, Co, Cu, S.

2. The most favorable conditions of the leaching are present at the continuous operating regime.

3. The acidic autoclave leaching of cobalt matte and anodic alloy adopted at the South-Ural-Nickel Combine has greatly simplified and cheapened the previous

scheme of production, and enables direct production of nickel-cobalt solutions.

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(pp.30-34)

By A. V. Vanyukov, Mintsvetzoloto

New processes in the domestic metallurgy of oxidised nickel ores

The nickel enterprises processing oxidised ores were created in the years of the first Five-year Plan.

The first domestic nickel industry, the Ural Nickel Works, was planned and constructed with the participation of foreign specialists, who gave their advice on the selection of the technologies and equipments. By way of example there may be mentioned the roasting of the fine matte, which was carried out in a reverberatory furnace with manual raking; for the reduction of the nickel protoxide it was decided to mix it with flour, to make rondelles, and to reduce them in the retort furnace. In the course of the years the staff of the Ural Nickel Works has devoted much work to improving the technologies and intensifying the processes. There was mastered the melting of thenickel protoxide to metal in the electric furnace; the roasting of the fine matte was changed from the hearth furnace to mechanical multi-hearth and tubular furnaces. The staff of the work deserves great credit for mastering the technology of the production of cobalt from converter slag.

The Ural Works has been very successful in the intensification of shaft melting and in improving the designs of the apparatuses. As the first works in the Soviet Union to melt nickel from ore it was a school for the workers of the nickel industry, and its accumulated experiences were of great importance in the creation and development of the domestic metallurgy of nickel.

In a relatively short time our works formulated and introduced many new processes and radically improved the technological scheme of the processing of oxidised ores to matte, which made it possible considerably to increase the planned capacity, and to lower the expenditures of fuel, electroenergy, chemicals.

In the present article there are reported some fundamental improvements in the technologies carried out in recent years at the nickel works engaged in the processing of oxidised nickel ores.

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At the South-Ural Combine there was found an original technical solution for increasing the productivity of the agglomerating machines. The charge, after being roasted under the first-roasted ore, is intermixed with a special mechanism, and, after leveling with the knife, is again roasted and agglomerated. Increasing the temperature inside the layer of charge to 60-70deg after its intermixing gives an increase in the productivity of the agglomerating machine of 10-15%, despite the reduction of the suction area by the area occupied by the mixing mechanism. The productivity can also be increased by decreasing the thickness of the caking layer from 350 according to the plan to 200 mm, and employment of a flexible packing at the contact between the vacuum chamber and the pallet.

At the South-Ural-Nickel Combine there has been automated the velocity of movement of the pallet of the agglomerating machine, with utilization as the impulse of the considerable difference between the electroconductivities of the agglomerate and the charge.

The principal direction of the improvement of the process of shaft melting at all of the nickel works has been the search for the optimal air regime.

In the last 15 years the quantity of air blown into the shaft furnace per square meter section in the region of the tuyere has increased by 2-3 times and amounts at present to 45-60 cubic meters/minute, which was at first obtained by lowering the height of the pour. Such a change in the air regime is quickly manifested on the principal indices of shaft melting. Thus, the specific throughput at the Ural Works increased from 14.1 to 24.2 and at the South-Ural-Nickel Combines from 6.41 to 31.0 metric tons/square meter per 24 hours. The specific expenditure of fuel on shaft melting was considerably decreased.

However forced operation of the furnace because of lowering the height of the pour was necessary because it brings about a sharp increase in the temperature of the departing gases, increases the dust-removal and increases the content of carbon monoxide in the departing gases, that is, lowers the efficiency of utilization of the coke charged into the furnace; replacement of the blower with a larger one was impossible. For eliminating these disadvantages of the low pour the South-Ural-Nickel Combine modernised the blast shaft furnace, which was altered for working with an increased (from 3.5 to 4.5 meters) height of the pour, which gave in 1957 a saving of more than 10,000 metric tons of coke.

After changing the air-blowing means of the shaft furnace the Reshak Nickel Works also changed to a higher charge, which increased the extraction of nickel in the matte, but somewhat lowered the specific throughput.

Further intensification of the operation the shaft furnace, as shown by recent industrial trials, can be obtained by further increasing the height of the charge, and increasing the quantity of air and its velocity at the tuyere. Improving the quality of the charge is of primary importance for improving the technical-economic indices of shaft melting.

In recent years there has been noticed a tendency to lower the content of nickel in the matte for the purpose of decreasing the loss of nickel in the discarded slag of the shaft furnace. Thus, at the South-Ural-Nickel Combine the content of nickel in the matter was lowered from 21.76 (1948) to 15.9% (1957) at which the content of nickel in the slag was lowered from 0.21 to 0.178%.

Regulation of the composition of the matte occurs by employment of pyrite as the sulphidizer.

Extremely effective have been the changes in the technology of processing converter slags. At the South-Ural-Nickel Combine in the place of mutual reductive-sulphidative melting in the shaft furnace there has been adopted impoverishment of the converter slag in the liquid form in the heated converter, at which about 60% of the slag with a content of 0.17% Ni and 0.07% Co is sent to the dump. For impoverishment of the slag there is poured into the heated converter 2-4 cubic meters of matte, and then a portion (7-8 metric tons) of slag, and the converted is blown for approximately 1 minute. After standing for 10-20 minutes the slag is let out.

For more complete transfer of the cobalt into the converter slag at the cooking of fine matte there is utilised the ability of cobalt to under intensive oxidation and enter into the slag with a decrease in the content of iron in the mass below 3-5%. The operation of refining the fine matte from cobalt consists in bringing the mass to the "[illegible]" test, corresponding to a content of 1-3% Fe in it, taking a small fresh portion of matte, and following with blowing. By maintaining, by the addition into the converter of fresh matte, the content of iron in the matte at a level of 3-5%, the content of cobalt in the finished fine matte can be lowered to 0.3-0.5%.

The introduction of schemes for the impoverishment of converter slags has enabled decreasing by 40% the quantity of slag subjected to melting in the shaft furnace, and increasing the extraction of cobalt in the melting shop from 35-40 to 62-65%.

In the last decade much effort has been devoted to seeking a method for decoppering fine matte. Of the works carried out in this direction there may be mentioned the methods of magnetic separation and sulphate-chlorination roasting. If the fine matte contains 0.9-0.9% Cu, there can be successfully employed magnetic separation of the roasted fine matte after grinding it. The yield of magnetic fraction containing 2-2.5% Cu after the second roasting is 15-30%, while the nonmagnetic fraction contains 0.3-0.4% Cu. At a higher content of copper in the starting fine matte (1.0% and more) there is employed for the decoppering sulphate-chlorination roasting of the cinder. The cinder after the first roasting at temperature 700-850 deg is brought directly from the roasting furnace into the "reactor" - a roasting drum of diameter 1.6 meters and length 10 meters, lined over half its length.

Simultaneously there is charged into the reactor sylivinite in a quantity of 7-15% of the weight of the cinder depending on its content of copper. In the process of chlorination and sulphatization, which occurs on account of the heat of cindering, 70-80% Cu changes into water-soluble form. The content of copper in the cake after leaching is usually 0.35-0.40%.

There have been improved the technical-economic indices of electromelting of nickel protoxide. The average weight of the melt has increased more than 30%, the expenditure of electroenergy has decreased 25%, which was obtained by partial automation of the operating regime of the furnace and replacement of wood charcoal with petroleum coke, enabling an increase in the pouring weight of the charge and the velocity of its heating.

In the field of the electrolysis of nickel the South-Ural-Nickel Combine has in recent years mastered the process of the production of electrolytical nickel powder and the production of particularly pure nickel. At the same place there was formulated a scheme for the processing of cemented copper (a product occurring at the purification of electrolyte from copper with nickel powder) with extraction from it of nickel, and production of commercial copper sulphate.

In the field of hydrometallurgy the efforts have been directed mainly to increasing the purity of the obtained cobalt hydroxide and metallic nickel, and to mastering the processing of arsenic-cobalt concentrate.

In the field of the pyrometallurgy of oxidised nickel ores there have been widely carried on in recent years semiindustrial experiments on improving the preparation of the charge and the melting of the ores.

Industrial experiments have also been carried out on the production and melting of sulphidised agglomerate; the obtained data have been used for planning reconstructions at the South-Ural-Nickel Combine; there has been tried the agglomeration of a charge preliminarily densified with specialrolls; experiments carried out on shaft melting of fluxed agglomerate indicated the possibility of increasing the specific throughput of agglomerate by 10-15% at a decrease in the expenditure of coke of 3%.

A radical improvement in the quality of the agglomerate can be obtained by changing the method of caking the ore. Semiindustrial experiments have shown that an agglomerate which fully satisfies all of the requirements for shaft melting can be obtained in the tubular furnace.

In the field of shaft melting there is promising the employment of heated blasts. Experiments being carried out at the present time show that by heating the blast to 200deg the expenditure of coke is decreased 25% at some increase in the productivity of the shaft furnace.

[illegible] a long time [illegible] way on operation of the shaft furnace with a blast enriched [illegible] oxygen. The experiments show that at enrichment of the blast with [illegible] oxygen [illegible] productivity of the furnace is increased [illegible] and the expenditure of fuel [illegible] decreased [illegible]%. However, at the experiments there has been observed [illegible] increase in the content of nickel in the [illegible] slag. Lowering of the cost of electroenergy and the creation of [illegible] the possibility of wide employment [illegible] nickel ores.

[illegible] the Institute of Gipro-[illegible] has in recent years been carrying on experiments on melting ore-carbon briquettes in the shaft furnace. [illegible] difficulty of the melting of the briquettes [illegible] in the hearth of the shaft furnace.

[illegible] is that of lowering the loss of metals [illegible]. For this purpose there have been tried the [illegible] stand in exterior settling tanks, of [illegible] various sulphidizers (aluminum sulphide, calcium sulphide, [illegible] sulphide, etc), [illegible] on separating the nickel from the slag [illegible] (for example, with iron), centrifuging and electrolysis.

[illegible] great interest [illegible] of exterior settling tanks for shaft furnaces. [illegible] success has already been attained in this direction. South-[illegible] a considerable decrease in the quantity of [illegible] which facilitates the furnace operation.

At the [illegible] is extracted in commercial [illegible] considerable importance the method of [illegible] cobalt and other [illegible] from the fine matte by treating [illegible]. For the same purpose there are being conducted [illegible] of oxygen at the sulphate-chlorination roasting of [illegible].

Of considerable interest from the viewpoint of increasing the complexity of the utilization of the raw materials is the solution of the problem of the employment of waste slags for the production of various kinds of products, as well as the utilization of secondary energy resources. In this direction there have been carried out in the nickel industry semiindustrial experiments on the employment of diphenyl mixtures for the cooling of caissons, which demonstrated in principle the possibility of utilising the heat of heat-carriers for the production of steam. Positive results have also been obtained at the trial of methods for the production of blocks and slagwool from waste slags.

Since the largest quantities of the pyrogenic nickels are employed for the melting of low- and medium-alloyed steels, there has recently begun to attract considerable attention the employment of nickel protoxide instead of metallic nickel for the melting of some sorts of steels in the Martin furnace. Experiments have been carried out on the nodulising of nickel protoxide in the tubular furnace for formulating conditions for its wider employment in the steel industry without danger of increasing the losses due to inflammation of the non-nodulised protoxide.

In the field of hydrometallurgy the South-Ural-Nickel Combine is studying the possibility of the employment of the autoclave process for the processing of cobalt-containing sulphide-material.

The South-Ural-Nickel Combine is interested in and is at present carrying out experiments in one of its industrial electrolysis tanks on the process of producing zinc hydrates by electrolysis.

Of the new technological schemes for the processing of oxidised nickel ores which have already been formulated there may be mentioned the following: reductive-sulphidising roasting of the ore in the tubular furnace followed by separation of the nickel concentrate by flotation; melting of the ore in the shaft furnace to phosphide alloys; reductive roasting of the ore followed by magnetic separation; reductive melting of oxidised nickel ore to high-alloyed cast-iron and ferronickel.

Semi-industrial experiments recently carried out for verifying the method of reductive-sulphidising roasting of the ore followed by enrichment have demonstrated the possibility of separating out a nickel concentrate with a content of 3-8% Ni and a nickel extraction of 90-95%. This method is now receiving all-sided study for the purpose of obtaining the starting data for technical-economic calculations.

Semiindustrial experiments have demonstrated the possibility of melting the ore to phosphide alloys with employment of a blast enriched with oxygen, lowering the content of nickel in the waste slag, producing phosphorite fertiliser, etc.

Reductive melting of the ores to ferronickel gives a high extraction of the nickel and cobalt and at the same time enables utilisation of the iron. However, the subsequent processing of the ferronickel for the purpose of obtaining commercial nickel, cobalt and iron encounters considerable difficulties. Because of this the reductive melting is at present feasible only for ores with a small content of cobalt, at which the ferronickel can be employed directly as an alloying addition at the production of steels in ferrous metallurgy.

For the ores recently discovered in the Buryktalsk deposits, which contain besides nickel and cobalt also considerable quantities of iron, there have been proposed a number of experimental technological scheme of reductive roasting of the ore following magnetic separation of the cinder and production of iron-cobalt-nickel concentration. For the ores of the Buryktalsk type there have also been proposed pyrometallurgical schemes and their combination with pyroprocesses.

Even this brief account of the projects carried out shows that in the field of the improvement of the technology of the processing of oxidized nickel ores the domestic industry has achieved considerable success.

The supplies of oxidized nickels ores increase with each year. The favorable geological prognoses and the considerable supplies of balance ores confronts the scientific-research workers and the research institutes and the industry with the problems of further improving the existing technological scheme, the formulation and introduction of new effective methods for the complex processing of the ores.

(pp 23-30)

By Prof. A.L. Rotinyan, Gipronikel'

Experiments on the production of electrolytical nickel

Electrolytical refining of the crude nickel is the concluding process of the production of commercial nickel from nickel ore. This process enables the production of a metal of very high purity.

The process of electrolysis of nickel has been researched in other countries for a fairly long time. The first experiments go back to the end of the last century.

In Russia in 1904 the electrolysis of nickel was studied L.L. Romanov (1), and then in 1916 P.P.Fedot'ev began to carry out detailed investigations (2). However, these investigations were not applied in the industry at the time. Extensive works on the electrolytical refining ofnickel began a quarter of a century ago in connection with the creation in the USSR of a domestic production of nickel.

The research results together with the literature information on the researches of foreign works enable Soyuznikel'olovoproyekt to plan a shop for the electrolysis ofnickel, which was constructed in a short time, and after 15 years is supplying the demand of our industry for electrolytical nickel of high purity.

The fundamental scheme of the process of electrolytical refining is the same everywhere. It consists of the purification of the electrolyte followed by the actual process of electrolysis. The electrolysis is carried out in a tank with a canvas diaphragm. Each of the cathodes is placed in a diaphragm cell, in which the admixtures are removed from the electrolyte at a certain velocity. In the cells the level of the solution is maintained higher than in the tank, thanks to which there proceeds a flow (filtration) of the electrolyte from the cathodic cell to the anodic space.

The solution of the nickel anode may contain various quantities of elements.

At the North-Nickel Combine, for example, in the course of a certain time (3) there were processed anodes of the following composition: 91% Ni, 1.8% Fe, 1.3% Co, 4.4% Cu, 0.9% S.

From the electrolyte there is usually removed the copper, iron and cobalt and sometimes also the zinc, and which the sequence of the operations and the methods of carrying them out are variable.

Electrolysis

The nickel electrolyte employed in the domestic works 12-15 years ago (4) contained (in grams/liter): Ni (in the form of $NiSO_4$) 40, Na_2SO_4 40, NaCl 5, H_3BO_3 20.

The electrolyte of this composition possessed a small electroconductivity, and the resulting small concentration of nickel did not enable operating at a current density above 130 amp/square meter.

The firm of INKO formulated (5) a so-called sulphate-chloride electrolyte, in which the concentration of sodium chloride was increased to 60 grams/liter and that of nickel to 45 grams/liter, while the content of nickel sulphate was decreased to 20 grams/liter. The concentration of boric acid remained unchanged at 20 grams/liter. This electrolyte possesses a greater electroconductivity, and enables operating at a current density of 170 amp/square meter.

As the result of investigations on intensification of the regime of the electrolysis, in particular by the creation of conditions for steady operation at a current density of 200 amp/square meter, carried out in the USSR, there was formulated another composition of the electrolyte, that is (in grams/liter): Ni 60, NaCl 40-50, Na_2SO_4 60, H_3BO_3 3-6. The distinguishing particularity of this electrolyte in comparison with the one employed in Canada are the greater concentrations in it of nickel and sodium sulphate and the smaller concentrations of sodium chloride and boric acid.

The higher concentration of nickel in the electrolyte gives the possibility of obtaining a dense, relatively-smooth precipitation at a high cathodic current density. The investigations showed that with increasing concentration of sodium chloride in the solution there occurs an increasing internal tension in the precipitated nickel. Therefore, while an increasing concentration of sodium chloride is accompanied by an increasing specific electroconductivity, nevertheless there is reached a limit at which there is formed a precipitate of the metal which is still sufficiently soft. The lowering of the concentration of boric acid in the nickel electrolyte was due to the shortage and dearness of this material. From the purely technical viewpoint, maintenance of the concentration of boric acid at 15-20 grams/liter is desirable. Investigations have shown that the electrolysis of a solution with a low concentration of boric acid can be carried out not only at a low pH ((P. P. Fedot'ev (2) and M. A. Loshkarev (17)) but also at a high pH (6). Investigations on increasing the cathodic current density at the electrolysis were begun early, simultaneously with the formulation of the original regime of the electrolysis at a current density of 130 amp/square meter, and have been continued to the present time. In 1939 A. A. Bulakh and L. N. Loshkin (7) proposed that the process be intensified by increasing the current density to 250 amp/square meter. In 1940 M. A. Loshkarev and G. B. Lapp (8) carried out an experimental research for confirming the possibility of obtaining metallic nickel at a current density of 260 amp/square meter. The suitability of increasing the cathodic current density is closely connected with the so-called economic current density. Calculations carried at the institute of Gipronikel' relating to the conditions at the North-Nickel Combine showed that at increasing the current density from 130 to 200 amp/square meter the total specific expenditure per metric ton is sharply lowered, but then up to 330 amp/square meter remains practically constant.

Although the intensification of the process by increasing the cathodic current density is economically justified, the practical gain in this direction is small. A further substantial increase in the current density will probably be obtained by changing to purely chloride electrolyte, which gives the possibility of operating at a current density of 400-800 amp/square meter. For this purpose N. P. Fedot'ev and Z. I. Dmitrennova (9) proposed an electrolyte of the following composition (in grams/liter): $NiCl_2.6H_2O$ 202, NaCl 108, H_3BO_3 18.

Recently the author of the present article, V. L. Kheifets and K. S. Kosich found experimentally that the process of refining at current densities up to 800 amp/square meter can be carried at lowered circulation and without buffering and current-conducting additions by employing a solution ofnickel chloride with a content of 130-150 grams/liter Ni.

However, the employment of such an electrolyte apparently leads to a change in the conditions of its purification.

B. V. Drozdov (10) reported the suitability of increasing the ampere load in the tank without increasing the cathodic current density for improving the utilization of its volume.

At the original construction of the nickel-electrolysis shop there was installed an electrolyzing tank of volume 8.25 cubic meters, in which there were placed 30 cathodes and 31 anodes. The total surface of the cathodes was 38.4 square meters and the load in the tank 5000 amp.

By increasing the total cathodic surface to 50 square meters by bringing the electrodes closer together and increasing their dimensions the North-Nickel Combine was able to bring to load in the tank to 10,000 amp and in some of the furnace operating periods even more (a). In the practice, therefore, intensification of the process of electrolysis has been obtained by increasing the cathodic current density as well as by better utilization of the existing electrolysis tank.

The high electronegative potential of nickel and the great electrodic polarization at discharge and ionization bring it about that there undergoes anodic dissolution not only the principal metal but also many admixtures which are more electropositive than nickel. On the cathode there proceeds the discharge of nickel ions as well as of the majority of admixtures going from the anode into the solution.

Moreover, there may be separated out the cathode hydrogen ions, whose discharge proceeds at a small overvoltage. The necessity of obtaining a high cathodic current output makes it necessary to carry out the electrolysis in a narrow acidity range of the electrolyte.

As can be seen from figure 1 at a pH below 2 for a sulphate electrolyte containing 5 grams/liter NaCl and at a pH of approximately 1.5 for an electrolyte containing 50 grams/liter NaCl the current output begins to fall sharply. A higher current output is obtained with increasing concentration of chlorine ions in the solution. This is due to the adsorption of the surface-active chlorine-ions on the cathode, which facilitates the discharge of the bivalent nickel ions considerably more than it facilitates the discharge of the univalent hydrogen ions.

With increasing pH the current output increases, approaching 100%, but in the practice there exists a certain critical value of pH, above which it cannot be increased, because in the electrolyte there begin to appear colloidal particles, which, in being adsorbed on the surface of the cathode, retard the normal growth of the crystals of the metal. This leads to a change in the crystalline structure of the deposit, and therewith to a worsening of its mechanical characteristics (12). At increasing the critical value of pH (pH_{cr} equals approximately 5.2) there sharply increases the internal tension in the deposits, increases their hardness and decreases their density and elasticity. There is also increased the contamination of the deposit with hydrogen and oxygen. The increased internal tension and hardness lead to warping of the cathodic sheets in the tank, and therewith to shortcircuiting of the diaphragms and complication of their removal from the cell and their repair. The lower density of the metal is the result of the decreased arrangement of its crystalline structure, and leads to the occurrence of porosity. The greater internal tension in the metal leads to microcracks, which, as also the pores, are filled with electrolyte; the latter is difficult to remove, so that there is increased the probability of contamination of the deposited nickel with sulphur.

The literature contains statements that with increasing cathodic current density there occurs increasing internal tension in the deposit, but A. I. Zhurin found that this view is erroneous. The internal tension does not increase at increasing current density if the pH in the cell does not go above the critical value.

At the dissolution of the nickel anodes the admixtures go into the electrolyte, and their concentration becomes much greater than the permissible in the neighborhood of the cathodes. Therefore the cathode and anode are separated by the filtering diaphragm, and the electrolyte is purified in the cathodic space.

It was previously thought that at the electrolysis the ions of the admixtures were deposited on the cathode in accordance with their electrochemical potential. For example, that copper was deposited in a greater degree than cobalt. However, more detailed study of the process of electrolysis (13) showed that this is not the case. Due to the low concentration of the ions of the admixtures they are discharged according to the limit current, that is, the velocity of their deposition is limited by the velocity of their transport to the surface of the cathode. Consequently the quantities of deposited admixtures are directly proportional with their concentration in the solution and inversely proportional with the current density, and do not depend on the nature of the ions of the admixtures and on the composition of the electrolyte.

Figure 1: Influence of pH of electrolyte on cathodic current output of nickel (11). (1) electrolyte containing 5 grams/liter NaCl; (2) electrolyte containing 50 grams/liter NaCl. (a) output of Ni referred to current, %

At the limit current there are discharged not only electropositive admixtures but also (because of the depolarisation effect due to the formation of a solid solution) electronegative admixtures, as, for example, zinc. Under the conditions of the electrolysis of nickel all of the admixtures to be removed from the solution are deposited at the limit current, which greatly facilitates the determination of the limit permissible concentration of the admixtures at the production of a given mark of cathodic nickel. At electrolyte at D equals approximately 170-200 amp/square meter and temperature 50-60deg it was found that each milligram of admixture in the catholyte corresponds to 0.003-0.004% of admixture in the cathodic nickel.

If admixtures do not penetrate from the anodic space, then their concentra-

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tion in the cell (C_{y_a}) is determined by the equation (14):

Cya equals C_p ((Q)/(Q plus K)),

where C_p is the concentration of the admixtures in the arriving electrolyte, Q is the velocity of flow of the electrolyte through the cell and K is the constant of the velocity of convective diffusion of the ions.

The experimental data show that under conditions close to the practical Q is greater than K and (Q)/(Q plus K) is a little smaller than unity. Consequently for practical purposes it may be assumed that each milligram of admixture in the electrolyte before its arrival in the cathodic cell contaminates the deposit of cathodic nickel with three-four thousandths of one per cent.

However, the diaphragm is not always able fully to protect the cathodic space against arrival therein of admixtures from the anodic space, and their penetration through the diaphragm by diffusion and migration is prevented by the counterflow of electrolyte in the pores of the diaphragm, where its level is higher than in the anodic space.

Consequently, the greater the velocity of flow of the electrolyte through the diaphragm is, the more completely are the ions of the admixture, which are transported in its pores from adnoe to cathode, transported by the stream of electrolyte back into the anodic space. But, the greater the velocity of flow of the catholyte through the cell, the greater is the volume of solution (and hence also the greater is the quantity of admixtures) passing per unit time through the cell, and hence also the greater is the degree of contamination of the cathodic deposit with admixtures. The simultaneous of these positive and negative factors is such that it determines for the given concrete conditions the velocity of circulation at which the degree of contamination of the deposit with admixtures is the smallest (figure 2). Of course, the greater the purity of the catholyte is, the farther is the minimum on the curve displaced in the direction of high velocity of flow, and conversely.

Figure 2: Influence of velocity of flow of electrolyte through cell on degree

of contamination with copper of cathodic nickel (according to data of B. P. Levin and A. S. Bushkants. (open circles) D_k equals 215 amp/square meter; (solid circles) D_k equals 170 amp/saure meter. (a) content of Cu in Ni, %; (b) velocity of flow to cell, liters/hr

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For the real conditions of electrolysis, indicated in the legend of figure 2, there was found an optimal velocity of flow to the cell of the order of 16 liters/hr. At a velocity of flow greater than the stated value it may be assumed that the arrival of admixtures from anodic into the cathodic space is very small.

Purification of electrolyte

Removal of copper: The removal from nickel electrolyte of copper occurs everywhere by the method of its cementation with nickel powder.

In correspondence with the normal electrochemical potential the reaction Cu^{2pos} plus Ni goes into Ni^{2pos} plus Cu must proceed practically to completion. However, the tendency of nickel to passivation makes this reaction very unstable. The depth of purification of the electrolyte from copper is determined by the activity of the employed nickel powered and by the conditions of carrying out the process cementation, so that a large number of investigations were made for formulating the technology of obtaining highly-active nickel-powder.

The most-active nickel-powder was obtained by reducing nickel protoxide with a gaseous reducer (generator gas, hydrogen) under strictly definite conditions, although very satisfactory results were also obtained at the employment of solid reducers (carbon). It was precisely this method of obtaining the powder which was first introduced into the practice of the electrolysis of nickel (b).

The process of cementation occurs either in a tank with mechanical agitation or by sucking the contamined solution through a layer ofnickel powder. The first method is at present at foreign enterprises and at the Norilsk Combine. This method was adopted for our first nickel works. Later there was widely adopted the method of sucking-through (percolation) formulated by A. A. Bulakh. The method is reliable, does not require filtration of the solution, and gives the possibility of deep purification of the solution with coarse nickel powder of low activity.

However, the necessity of the employment of hard manual labor and the impossibility of mechanization of the process has brought it about that at the present time there is a tendency to replace the percolation method of the purification of the electrolyte from copper with the agitation method.

Purification from iron: The purification of the electrolyte occurs everywhere by precipitation of the iron in the form of the little-soluble hydroxide or basic salts of the trivalent metal. But, since at the anode the iron goes into solution in the bivalent form, the precipitation of the hydroxide proceeds simultaneously with oxidation of Fe to Fe^{3pos} by air. Neutralization of the excessive acidity occurs with nickel carbonate. The so-called iron cake obtained in this way contains much iron, and it is repulped. According to the literature (5), in sulphate-chloride electrolyte there can proceed the process of precipitation of iron hydroxide without the employment of an alkaline reagent, on account of the ions of univalent copper, which are oxidized by the oxygen of the air to the bivalent state, binding the hydrogen ions according to the reaction

$2Cu^{pos}$ plus $2H^{pos}$ plus O goes into $2Cu^{2pos}$ plus H_2O.

However, the attempts to employ this process under the conditions of electrolysis at our enterprises have not so far been successful. It is necessary to agree with the view of V. N. Rozov (3) that the attainments of our industry in the process of iron-purification are insignificant. The great difficulties here the poor filtrability of the primary iron cake and the great expenditure of reagents. The experiments on replacing the filter-press with a more productive apparatus (centrifuge or separator) are not yet completed but have given hopeful results. The main difficulty in solving this problem is the high aggressiveness of the solution arriving for filtration.

Purification from cobalt: Purification of the nickel electrolyte from cobalt was carried out from the first day of operation of the domestic electrolysis shops, when apparently an analogous process was not yet carried out in foreign countries, and was not described in the literature.

In the USSR there have been formulated and carried out on an industrial scale three methods of purifying the solution from coblat. These methods are based on hydrolytical removal of the insignificantly-soluble hydroxide of trivalent cobalt from the precipitate followed by separation of the precipitate from the liquid phase. However, the cobalt ions are present in solution in the bivalent form, so that a preliminary stage of the process is their oxidation to the trivalent state. The standard oxidative-reductive potential of the system Co^{3pos}-Co^{2pos} is so great that oxygen does not oxidise the Co^{2pos} ion, and it becomes necessary to employ a stronger oxidiser.

In the first of theindustrial methods there was employed as the oxidiser the "black hydrate" of nickel, that is, anickel hydroxide with a high degree of oxidation.

The hydroxide of thehigher nickel oxide, whose composition is not yet precisely known, oxidises the cobalt ion to the trivalent state according to a reaction which may be schematically represented as follows:

$Ni(OH)_{3mv}$ plus $CoSO_4$ goes into $Co(OH)_{3mv}$ plus $NiSO_4$.

The success of this process is principally determined by the ability to obtain the highly-active "black hydrate".

Figure 3: Variation in oxidative-reductive potential of electrolyte at precipitation of cobalt with gaseous chlorine. (I and II) oxidative-reductive potential; (I' and II') quantity of Na2CO3 in mg expended on maintaining the value of pH (4.2 and 5.0). (According to the data of E. F. Kreail'nikov.) (a) oxidative-reductive potential, volts; (b) minutes

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However, its disadvantages (high expenditure of reagents a relatively shallow purification of the solution from cobalt) made it necessary to seek other methods, and the success in this field has been so great that at the present time the above-described method of purification ofnickel electrolyte from cobalt finds only limited application.

The coworkers of the South-Ural-Nickel Combine (L. L. Chermak, N. F. Uspenskii, B.N.Polyakov, M.P.Petrov) formulated an electrolytical method for the purification of the electrolyte from cobalt based on oxidation of the cobalt ion with chlorine, which separates out at the graphite anode in the electrolysis tank. For this purpose the electrolyte is passed through the electrolysis tank, as whose cathode there serves a nickel base and as whose anode a graphite block. A diaphragm is not employed here. For preventing overacidification of the solution in the tank there is continuously added pulp of nickel carbonate. At the cathode there proceeds deposition of low-quality nickel and at the anode combined discharge of chlorine ions and hydroxide. The anodix current yield of chlorine, which also oxidizes the cobalt ions, is small, not going above 10%. At the anode, therefore, there is principally separated out oxygen and formed acid, which is a disadvantage of the method, because all of the irrationally-forming acid must be neutralized with carbonate. Moreover, the solid phase (cake), forming at this method contains several times more nickel than cobalt, so that the further separation of the nickel and cobalt requires a considerable expenditure of reagents (adis and soda).

A better and more economical method for the purification of the nickel electrolyte from cobalt was formulated by B. N. Rozov (3) and improved by O. O. Kasherininov (15). This method consists in passing gaseous chlorine through the heated nickel electrolyte with simultaneous neutralization of the acid forming with nickel cabbonate. An analogous process was formulated in the United States (16).

This process can be represented by the equation:

$2Co^{2pos}$ plus Cl_2 plus 6OH' goes into 2Cl' plus $2Co(OH)_3$.

In passing through the electrolyte the chlorine gas is dissolved in it, partly transformed into hypochlorite and hypochlorous acid, and creating in the solution a high oxidative potential. Upon reaching a potential of the order of pos 1.0-1.1 volt there begins oxidation of bivalent ions of cobalt and simultaneously formation of precipitate.

Figure 4: Influence of value of pH of electrolyte on depth of precipitation of cobalt and the ratio Ni : Co in the cake (Velocity of passage of chlorine 12 ml/

min). (1) depth of precipitation of cobalt, %; (2) expenditure of NaOH on precipitation of cobalt, grams/mg; (3) ratio Ni : Co in precipitate. (a) precipitated nickel, %; (b) NaOH per mg cobalt, grams

As can be seen from figure 3, in the first minute of the passage of the chlorine there occurs an increase in the oxidative potential to a value of the order of pos 1.0-1.1 volts. At this there is expended a small quantity of alkali, probably on neutralisation of the acid forming as a result of hydrolysis of chlorine, but a formation of cobalt hydroxide doesnot occur. When the potential reaches the stated value there beings to form black precipitate of hydroxide, and alkali is expended until complete disappearance of bivalent ions of cobalt.

Another factor influencing the depth of purification of the nickel electrolyte from cobalt is the value of the pH of the solution. Curves illustrating this dependence, obtained by the author and V. Y. Zal'des, are presented in fig.4. From the curves it can be seen that the process of purification of the electrolyte must be carried out in a fairly narrow range of variation of pH - about the value 4.0 (approximately at 70deg). If the pH is much greater there being intensive coprecipitation ofnickel hydroxide, which worsens the composition of the cake and requires supplementary expenditure of alkali.

With this method of purification of the electrolyte from cobalt it is possible to leave remaining in the solution not more than 10-15 mg/liter cobalt and to obtain a cake with a ratio of cobalt tonickel of approximately 0.5. Further treatment of the primary cobalt cake, according to the proposal of V.M.Tseiper, is carried out by dissolving a part of the cake in sulphuric acid and repulping the remaining part in this solution. The oxidic compounds of nickel present in the cake oxidise the cobalt in the solution, as a result of which there occurs an impoverishment of the cake in nickel and a separation of the cobalt from the solution. After this operation there is obtained the so-called cobalt concentrate, which is employed in the cobalt production.

Purification of the electrolyte from zinc: In some cases, when the sulphuric acid available for the production of cathodic nickel contains a considerable quantity (more than 0.2 gram/liter) of zinc, the latter, passing through all of the stages of the usual operations of the purification of the electrolyte, unavoidably gets into the cathodic deposit, which leads to downgrading of the cathodic nickel.

Under these conditions it has been necessary to introduce a supplementary special operation of the purification of the electrolyte from zinc with soda (South-Ural-Nickel Combine). At this there are formed insolube zinc- and nickel-carbonate, which are removed in the form of cake from the electrolyte, and subject to pyrometallurgical processing. The quantity of nickel in thenickel-zinc cake is very considerable, so that the employemtn of zinc-containing reagents at the electrolysis of nickel is abolutely undesirable.

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Footnotes

(a) There participated in the work A.A.Grigor'eva, V.P.Golybeva, P.K.Ponomarenko, S.K.Karapetyan and others.

(b) The introduction of this method was carried out by M. I. Zakharov, B.V. Lipin and V.Y.Posyanakov.

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By V. I. Mikhailov and B. I. Matusevich, Ufaleisk Nickel Works

Firstborn of the Soviet Nickel Industry.

Twenty-five years ago, 1933, there was completed the construction of taken into operation the first enterprise of the Soviet nickel industry - the Ufaleisk Nickel Works.

Interesting and characteristic is the history of the formulation and improvement of the art at this works.

The planning, construction of the works and the development of the geoprospecting for nickel in the Ufaleisk region had been authorized already in 1927 at the Second All-Union Conference on Nonferrous Metals in Moscow. The planning work was begun the same year. The most economical of the considered variants of the technological scheme for the planned works was found to be scheme consisting in caking of the ore followed by melting of the agglomerates in the waterjacket furnace. This variant was confirmed in 1929.

At the consideration of the proeject there was established the possibility of planning the works for a large capacity.

The instructions on the technical planning of the works, issued by Gipromez (Leningrad), in September 1939, contemplated a works with a capacity 3 times greater than that originally contemplated. At the reorganization and splitting-up of Gipromez, Giprotsvetmet (Leningrad branch) took in hand the formulation of the technical plan. In the formulation of the plan there took active part technical adviser T. A. Obolduev, chief engineer of the project A. A. Tseidler and his assistant A. A. Mironov, and later V. V. Zakharov and A. A. Zadik'yan.

In April 1930 the technical plan was confirmed by the Technical Council of Glavtsvetmetzolot.

In May 1930, A. A. Mironov and A. A. Tseidler sought and obtained the expert advice of the Officeof Miller (USA) on the technical suitability of the plan. The

Office of Miller confirmed the suitability of the process of agglomeration of nickel ore.

However, at the insistent advice of the foreign specialist Boshich, the Technical Council of Glavtsvetmetzoloto decided to plan the Ufaleisk Nickel Works according to the scheme of briquetting of the ore followed by melting in the shaft furnace. This task was carried out by Uralgiprotsvetmet. Actually only the metallurgical part was modified: instead of the agglomerating shop there was planned a drying and briquetting shop, and, in the roasting shop, instead of a mechanical furnace, a reverberatory, single-hearth furnace with manual raking for gas heating.

Originally the technology of the production of nickel at the new works was based on the following scheme of production.

The ore arriving from the mine was crushed in a crusher, dried in a drying drum to a moisture content of 12-15%, mixed with gypsum and pyrites, and then briquetted on a roll press. The briquettes without drying were transported in a bucket conveyor to the furnace and charged into the water jacket together with lime, coke and slag.

The slag from the water jacket was granulated with water and let into the slag basin, from which it was transported by an overhead grab, loaded into a narrow-gauge railroad-car and transported to the dump. The crude matte in molten form was poured into the converter, blown to refined matte, and poured into molds; then the cooled refined matte was subjected to coarse grinding to pieces of approximately 200x200x400mm, and set to the roasting-reducing shop, where it was subjected first to crushing in the "Blek" crusher and then to fine grinding in the ball mill. The powder of crude matte was charged into the roasting furnace and roasted "dead", that is, to a sulphur content of 0.02%.

Nikolai Nikitovich Chekasii

The nickel protoxide (powder) was mixed with rye flour, moistened with water, and, after mixing in a special dough mixer, sent to the pressing department, equipped with a "During" press, for making cylinders (rondelles) of 25x15mm. The rondelles were dried in a heart [illegible] furnace, mixed with wood charcoal, and reduced to metal in a retort furnace. The finished metallic rondelles were roughly polished with sawdust in a rotating metal drum, then the sawdust was washed off, and the rondelles were dried, packaged and shipped to the consumer.

According to this technology the Ufaleisk Nickel Works operated until 1936, after which the scheme was somewhat modified.

During the construction of the work the patriotism of the Soviet people manifested widely and in many ways. [illegible] of the construction of the works buildings, yards, tanks, underground ways, roads as well as other objects of the works was finished in a short time.

Many of the first builders are still working at the works. Among them, G. P. Chashchin, one of the first to help prepare the site and build the first buildings of the works; [illegible] Andreev, the first installer at the construction and equipment of the works; I. [illegible] yankov, one of the first miners of the Tyulenyk Mine, now an excavator operator; K. I. Raskostov, a civil engineer, now master-foreman of the important furnace department of the melting shop of the works; I. A. Glazyrin, a nickel worker, who introduced at the works electromelting of nickel, now head melter of the electrofurnace department, whose valuable method of operation is described on a special instruction chart of the works; the method has now been adopted by other related enterprises of our country. V. A. Pimenov, melter, and others.

Also worthy of mention is the activity of the first director of the works, N. I. Chekmasin, Old Bolshevik, Red Partisan, recipient of two Orders of Lenin. The Party organization (Comrade Mart'yanov, Secretary), stimulated the staff of the works to greater achievements, saw to it that the orders of the Party and of the Government were carried out, and hastened the mastery ofthe production of Soviet nickel.

After establishing a smooth output of the scarce metal the staff of the works turned it's attention to the improvement of the technology, the construction of a second works, and the expansion of the shops to the planned capacity.

Aleksandr Alekseevich [illegible]

Melting shop of the Ufaleisk Nickel Works

Rashid [illegible]evich Kil'dibekov

Gennadii [illegible]evich Khleptin

Ivan Alekseevich [illegible]

Victor Aleksandrovich Pi[illegible]

At the same time there was carried out the reconstruction of the existing aggregates for increasing the productivity and improving the working conditions, and carried on works on mastering new technologies of the production of nickel.

In 1934-1935, after the introduction of melting the nickel protoxide to metal, the works was able to turn out a better nickel, and, in 1936, after taking into operation the electrofurnace department, the production of rondelles was discontinued.

The introduction and mastery of electromelting of nickel protoxide to commercial nickel was carried out by Engineer V. V. Zakharov under the direction of Chief Engineer of the Works A. . . Mironov. At the same there was mastered by the works the technology of the production of nickel sulphate and cobalt hydroxide.

Prof. [illegible] Baraboshkin and Engineer Vaneev carried out the experiments on the electrolysis of nickel refined matte, and after ward, in 1935, there was begun at the Ural Polytechnical Institute under the direction of Prof. I. G. Shcherbakov the work on the formulation of a scheme for the production of electrolytical nickel with participation of employees of the Ufaleisk Nickel Works (R. L. Kil'dibekov and others).

In 1.[illegible] there was taken into operation an experimental electrolysis shop, and since that time the works has been producing besides the pyrogeneous nickels also limited quantities of highgrade electrolytical nickels.

The results of the work of the electrolysis shop were utilized for formulating and mastering the process of the production of domestic electrolytical nickel on an industrial scale in other enterprises.

[illegible] 193[illegible] there was taken into operation a sulphate shop and by May 1st of that year there was produced the first ton of highgrade nickel sulphate. The first superintendent of the sulphate shop was A. S. Kil'dibekov. After the electrolysis and the sulphate shops were taken into operation there began to accumulate large quantities of cobalt-containing cake, whose presence gave the possibility of [illegible] in the operation scheme the production of the first domestic cobalt.

In the first quarter of 1937, a research group of the works formulated a so-called ammonia scheme for the production of cobalt, and by May 1st of that year there was produced under laboratory conditions the first 10 kg of domestic cobalt in the form of rondelles.

In the second half of 1937 there was installed and taken into operation a large experimental plant for the production of cobalt, in which the cobalt-containing waste occurring in the sulphate and electrolysis shops was processed to cobalt oxide.

Toward the end of 193[illegible] there was begun the construction of the cobalt shop, which was taken into operation in December 1939. The formulation, taking into operation and mastering of the technology of the production of cobalt were carried out under the direction of the superintendent of the shop Y. P. Shein with the active participation of the whole staff of workers; one of them, A. P. Zyazev, is still working as a technologist at the works. An active role in the establishment of the cobalt production was played by the worker G. [illegible] Khlepetin, now head of the laboratory of the works.

In the first half of 19[illegible] there was carried out the reorganization of the sulphate production. [illegible] the same time a team of the Institute of the Soyuznikel' olovproyekt ([illegible]), with [illegible] the works, formulated a technological scheme [illegible] the production of nickel- and cobalt-sulphate for the South-Ural-

Nickel Combine. In February 1[illegible] for remelting the converter slags to cobalt crude [illegible] the melting shop a special [illegible] installed and taken into operation the [illegible] for chlorination roasting of cobalt crude matte, re[illegible] for this purpose.

Actively participat[illegible] in mastering the process of chlorination roasting were: [illegible] Ivanov, [illegible] superintendent [illegible] roasting shop; [illegible] Khrisanfova, now sup[illegible], now retired on a pension; [illegible] now superintendent of a shift of the roasting shop.

In 19[illegible], the staff of the cobalt shop under the direction of the shop superintendent [illegible] mastered the processing of a new form of cobalt-containing raw-material, [illegible] cobalt-arsenic concentrate according to a technological scheme formulated by a research group of the works under the direction of engineers [illegible] and [illegible]. The processing of this concentrate has increased the production of cobalt.

In 1[illegible] the works began to process still another form of raw material - Dal'stroy concentrate. This has enabled a considerable increase in the output of cobalt [illegible].

[illegible], in 1[illegible], besides its principal productions, the works mastered the industrial production of two additional forms of production required by the national economy. During the war the works did not slacken the temp_o of the production of [illegible] from year to year increased the outputs of nickel sulphate and cobalt oxide. [illegible] the output of cobalt increased by several times [illegible].

In the postwar period the works has systematically increased the tempo of the [illegible] of the production and increased the [illegible]. The [illegible] the production of nickel was on the average [illegible].

[illegible] oxide was in 19[illegible]0 4 times and in 1953 [illegible] times greater than in 1946 - the first year of the fourth five-year plan.

[illegible] increased 4 times. The pro-[illegible] and that of the mine workers [illegible].

[illegible] improvements on mechanization [illegible] preventing a further increase in [illegible]. The working conditions were improved.

[illegible] for a general overhauling, [illegible] reconstruction and expansion [illegible] mechanization of tedious processes.

Grigorii Pavlovich Chashchin

[illegible]

Ivan Nikolaevich Andreev

In [illegible] the staff of the works proceeded with a reconstruction of the roasting-reducing shop, as a result of which the working conditions were radically changed: there was constructed an electrofilter, mechanized the process of roasting, by which the productive capacity of the furnace was greatly increased, and conditions for improving the technical-economic indices.

In the drying shop in 1948 (according to the proposal of Shop Superintendent [illegible]. Bazanov), there was mechanized the work of the loaders of the drying drums.

In the melting shop in [illegible] there was completed the construction of a slag [illegible]. In the [illegible] shop [illegible] reverberatory furnace and expanded [illegible] production. The reconstruction of the shop will be continued in accordance with the existing plan. At the same time with the expansion of the production, the mechanization of the tedious work and the improvement of the technology the staff of the works devoted much thought to the problem of improving the [illegible] indices of all of the segments and of improving the quality of the production.

The "firstborn of the nickel and cobalt industry in the country - the Ufaleisk [illegible] is a kind of school for the training of workers, engineer-techni- [illegible] of industry.

[illegible] the North-Nickel Combine were [illegible] valuable assistance by send- ing qualified workers, [illegible] engineer-technicians. Workers, masters and [illegible] works for mastering the tech- [illegible] necessary qualifications.

[illegible] persons who have been working here for more than 20 years, [illegible] very beginning, and also many productive workers who began working here before the war. The staff of the works depends on these cadres for solving the problems of improving the technologies and increasing the [illegible] there are many workers and engineer-techni- cians who have received [illegible] for long and irreproachable work: Order of Lenin [illegible] persons, [illegible] Red Banner 32 persons, medals "For Valiant [illegible]" "For Distinguished Work" [illegible] persons. The title of "Better [illegible] conferred on [illegible] operators, and the title of "Honorary Metallurgist" [illegible] metallurgists of the works.

[illegible] may be mentioned I. [illegible] Tarosov and [illegible] metallurgists [illegible] Glazyrin, I. A. Glazyrin, I. A. [illegible] Toksharov, who by their many years of conscien- tious effort [illegible] improved the technologies, lowered the losses and increased [illegible].

[illegible] production of the first Soviet nickel there [illegible] department, working here since [illegible] has been working here since 1941 in a furnace [illegible] Tchegailov, working here since [illegible] N. Klopin, who began here as an unskilled [illegible], the recipient of two Orders of [illegible] here since 1935, and now a master tubular-furnace operator; [illegible] Bunev, working here since 1935, and a [illegible] technologists, working here since 1937.

The staff [illegible] has carried out extensive projects [illegible] departments, on the gradual mechanization [illegible] of [illegible] production.

[illegible] all of the operations for charging [illegible] of the slag yard, which gave the [illegible] the removal of the slag from the shop; mechanized [illegible] furnaces; installed a 20-metric-ton horizontal-converter [illegible] replacing the vertical-converter of smaller capacity; installed additional [illegible] furnaces.

[illegible] are being installed in the melting shop.

The roasting [illegible] will be replaced with mechanical [illegible] electrofilters will be installed. [illegible] and drying of the nickel granules will be mechanized, as well as the transport of the nickel protoxide. In the cobalt shop there will be increased the capacity of the apparatuses, considerably expanded the department of finished production, mechanized the transport of loads and other operations now performed manually, as, for example, clamping of the filter-presses. [illegible] is being carriedout the reconstruction of the roasting department of the cobalt shop and the installation of the electro-filters.

The capacity of the railroads [illegible] considerably increased; for the mechanization of [illegible] has introduced a number of mechanisms [illegible] automobile runways, auto- and tractor-loaders, [illegible] locomotives. At the mines the loading of the [illegible] excavators, and mechanized [illegible], as already mentioned, of intensi[illegible] completely assures the sup[illegible].

In the other auxiliary shops, especially in the last 2-3 years, there has also [illegible] considerable work on mechanization of the processes.

[illegible] in the mechanization of the processes, the [illegible] technologies, increasing the produtivity of the aggregates and [illegible] have been the rationalizers and inventors, whose numbers are increasing every year. Thus, in 1935, the works had about 100 rationalizers [illegible] was more than 400. The savings from rationalization in [illegible] rubles while in 1957 they were more than 4,000,000 rubles.

Better rationalizers were I. I. Baibakov, fitter in the drying shop, A. E. [illegible], fitter in the car depot of the transport shop, A. T. Solov'ev, fitter in the cobalt shop, [illegible], gas-welder in the cobalt shop, I. M. Dremin, steam-locomotive operator of the transport shop, I. A. Titov, planer in the machine shop, V. I. Bulatov, electrowelder at the Chenomshansk mine, V. F. Zykun, steam-locomotive operator at the Tylenevsk mine, A. G. Evees, fitter in the roasting shop, [illegible], master in the cobalt shop, M. I. Cherepanov, master, bridge-crane operator of the [illegible] shop, I. I. Yakovlev, master in the autogarage, [illegible] Cherepanov, head electrician of the melting shop, and others.

The staff of the Ufaleisk Nickel Works overfulfills the plan every year, striving actively to improve the technical-productive indices of the work, improve the technical [illegible] the conditions of the work and culture of the operation.

From Tsvetnye Metally (Soviet Nonferrous Metals), 7, 1958, pp 3-65((except pp
20-22 (missing))

By .I. A. Strigin

Twenty-five years of the Soviet Nickel Industry

The progress of the contemporary arts is closely connected with the success in the development ofthe production and employment of nonferrous and rare metals enabling in alloys with iron and other metals the creation of materials distinguished by high corrosion stability, refractoriness, plasticity, increased mechanical strength and other valuable characteristics. The development of the art in the last five years has placed nickel and cobalt among the more important metals.

The first experiments on the utilization of domestic nickel, carried out toward the end of the last century, did not receive practical application in prerevolutionary Russia. It was only after the Great October Soviet Revolution that the production of domestic nickel became a problem of the economic development of the country.

At the beginning of the five-year plans of industrialization of the country the Soviet Union did not have a production of nickel and cobalt, and had insufficient information on the possible natural resources of these metals. The prospecting and detailed exploration for nickel ores of Soviet geologists disclosed regions with deposits of ores containing nickel and cobalt, thus enabling the creation of a domestic nickel industry on a solid basis of supply of raw materials.

In August, 1933, there entered into operation the first nickel industry - the Ufaleisk Nickel Works, and then in 1938-1941 the larger enterprises in South Ural and in Zapolyar.

The development of the nickel-cobalt industry has always attracted the special attention of the Party and of the Government.

During World War II the intensified efforts of the workers of the nickel-cobalt industry were directed toward more complete utilization of the production capacity of the existing enterprises and toward satisfying the demands of the defense industries for strategic materials.

It was also during this period that there was introduced at the Sourth-Ural Combine forces shaft molting of silicate nickel ore with employment of high elasticity of the blast, as a result of which the productivity of the shaft furnaces and the production of nickel was increased more than two times; for this technical improvement the group of engineers of the Soubh-Ural Combine received the Staline Prize.

The staff of the Norilsk Combine devoted much effort toward hastening under difficult conditions the incorporation of a new complex of enterprises in Zapolyar.

In the first years after the war the efforts of the workers of the nickel-cobalt industry enabled the restoration in a short time of the activities of the North-Nickel and the Pechenga-Nickel Combine.

Of the development of the nickel-cobalt industry in the recent period there is characteristic of further improvement of the technologies and a better utilization of the fundamental equipments of the enterprises.

In 1955, in comparison with 1950 the production of nickel was increased 1.37 times and the production of copper and cobalt from nickel ores more than 2 times. The increase was achieved by the elimination of bottle necks, by intensification and rationalization of the production, and by the adoption or more modern technologies. During these years the extraction from the ores of nickel was increased 5.5% and of cobalt 10% (absolute). The majority of nickel enterprises also turned out in 1956-1957, a considerably greater production of metals; in 1958, all of the enterprises are fincreasing their production goals from month to month.

The general increase in nickel-cobalt productivity is the result of themore creative activity of the workers, engineers, technicians, rationalizers and executives of the enterprises and of the planners and researchers of the institutes of nonferrous metallurgy, as well as of the higher level of eduction.

In the mining of nickel ores there is widely employed the progressive, highly-productive method of open mining.

In 1958 open mining accounted for more than 80% of all of the nickel ore. The share of this method will be increased in future years.

At the Kimpersaisk quarries the excavators work with the highest productivity in comparison with the other enterprises of nonferrous metallurgy. There has been repeatedly noted the success of the miners of Nittis-Kumuzh (North-Nickel Combine), in the organization of rapid depletion-mining of blocked-out sections. The staff of the mining enterprises of the Norilsk Combine carries on creative work on improvement and creation of new mining equipments.

One of the most important steps in the production of nickel from copper-nickel sulphide ores in their flotation enrichment.

The Norilsk Combine successfully solved the problem of selective flotation of poor sulphide copper-nickel ores. At the concentration works of this combine, one of the largest in the USSR, there is being continuously improved the technological scheme previously formulated in the laboratory and on the continuous apparatus of the engineering combined, modernized the equipment, and increased the efficiency of the extraction of the metals in the various concentrates and their selective separation. A considerable improvement in the work of the concentration works in 1957-1958, is the result of the adoption of a new stage scheme of grinding and classification with employment of hydrocyclones, and also the result of some improvements in the reagent regime. These measures were adopted by the combine was the direct help of the Machinery Institute.

The experiments of the Norilsk Combine on the enrichment of sulphide ores have also been extended to the enrichment of the analogous ores of the Kolsk Peninsula now being investigated and planned.

Twenty-five years ago, at the organization of the production of nickel on the basis of the only raw material available at the time (poor oxidic silicate nickel ores) the Soviet specialists had to solve a difficult problem. As is known, at that time in the world practice it was not regarded as possible to obtain nickel from such a poor and mineralogically-complex raw-material, so that the problem had to be solved on the basis of the experience of other productions first applied on a semiindustrial scale with taking account of the local conditions. There was employed shaft melting of agglomerates (South Ural Nickel), and of briquettes (Ufaleisk Works).

The road traveled by the nickel industry has been characterized by much work on modification of the design of the shaft furnace, the air regime, etc. Considerably increasing the productivity of the furnace and decreasing the loss of metal wi with the slag became the subjects of the scientific and technical activities of the engineers of these enterprises. However, these works were complete only after the formulation of measures for preparing the melting charge in the form of agglomerates or briquettes, which enable the exclusion of wet or underdried ore fromthe charge. The accumulation of experimental works and the large volume of we works investigations and experiences give the possibility of planning new works and modernizing old works on the basis of a better technological scheme assuring an increased production of nickel. By the works of Gipronickel, Gintsvetmet, Mintsvetmetzolot and the Ural Polytechnical Institute there have been found new ways for processing oxidic nickel ores, which give a better basis for selecting the technological scheme for the new Ural Works.

The electromeling of nickel ores and concentrates, employed at present as the fundamental metallurgical process at the North-Nickel and the Pechenga-Nickel Combine, is being constantly improved as a result of the creative work of the staffs of these enterprises.

Changing to electrofurnaces working with a deep tank, increasing the power of the furnace transformers by reconstructing them, and many other technical improvements, have given an increased productivity of the electrofurnace shop of the North-Nickel Combine of 30% and of the Pechenga-Nickel Combime of two times, and at the same time a decrease in the loss of metal with the discarded slag. The decision of the Norilsk Combine in 1958 to adopt electromelting of nickel concentrate has also lowered the loss of metal with the slag and given a number of other advantages, and eliminated the difficulties due to insufficient sulphur in the charge and the limited resources of coking coal of the combine.

The Norilsk Combine and later also the North-Nickel Combine have successfully adopted and mastered the method, proposed and formulated by Prof. I. N. Maslenitskii for the flotation separation of "converter matte with production of nickel and copper concentrates. The adoption of this method enabled elimination from the technological scheme of the processing of copper-nickel ores of tedious, inefficient and expensive operations, and lowering the loss of metal.

The staffs of the South-Ural-Nickel and the North-Nickel Combine with the participation of the Institutes of Gintsvetmet and Gipronickel formulated and mastered a technology for the production of nickel of high purity and particularly-pure nickel (99.99% Ni) necessary for the production of refractory alloys and many other products. The Institute of Gipronickel fully formulated in their experimental shop a technological process for the production of nickel by the carbonyl method under high pressure. Its industrial production is now being organised. The employment of such nickel in a number of branches of the national economy gives great economic advantages.

Many original investigations and radical improvements have been carried out in the nickel works for increasing the incidental extraction of cobalt from oxidic and sulphidic nickel ores at the conversion of nickel matte. The continuous improvements in the processes of the conversion of nickel matte and the operations of extracting the cobalt from converter slag assures an increase in the production of cobalt in step with the increase in the production of nickel.

The most important in the solution of this problem is the work of the South-Ural-Nickel Combine on the adoption of a scheme of processing of converter cobalt-containing slags in liquid form by impoverishing them in converter matte of the ore melt. The cobalt matte enriched according to this method is, for the purpose of separating from the cobalt the principal mass of nickel, converted to converter matte and rich converter slag. The latter is treated with poor matte with production of rich cobalt matte, which is then converted to cobalt alloy. The carrying out of this process at the South-Ural-Nickel Combine enabled an increase in the extraction of cobalt at the processing of the matte of 1.6-1.8 times, and a considerable enrichment of the anode with cobalt. Improvement in the cobalt production is being continued at the combine in the direction of a further increase in the extraction of cobalt in the process.

The carrying out at the North-Nickel Combine of electromelting of liquid converter slags has also contributed to increasing the extraction and further increasing the production of cobalt in 1957, and 1958.

In 25 years the nickel industry has development large numbers of specialists able to solve important scientific, technological and economic problems.

The workers of the nickel and cobalt industry are confronted with some important problems: To prospect and explore richer nickel and cobalt ores both in the regions of their enterprises and in new regions for the purpose of widening their raw-material basis and assuring their supply from rich ore veins; to increase the efficiency of the equipments and of the work at the mines of the nickel industry; to improve the processing of the ores at their preliminary enrichment, including oxidic nickel ores, for the purpose of reducing the operation losses at the melting of nickel-poor raw-materials; to reconstruct the existing enterprises on the basis of a more rational scheme of operation, with elimination of bottle necks and more complex utilization of the raw materials; to organize the production of sulphuric acid from metallurgical gases; to increase the extraction of nickel and cobalt at the works at the concentration of sulphidic ores and at the metallurgical works.

In view of the fact that at the majority of the enterprises the losses of nickel and cobalt still remain very high, the improvement of the extraction of the metal is the most factor in increasing the production of the metals. Smaller losses of metals have been obtained as a result of: The introduction of operation storages for neutral ores, of agglomerating works No. 2, and of dust-collecting systems in the works of the South Ural-Nickel Combine; changing to electromelting of nickel concentrates and introduction of dust-collecting systems into the existing shops of the works of the Norilsk Combine; neutralizing the ores, dyring and sprinkling the charge before electromelting at the metallurgical works of the North-Nickel and the Pechenga-Nickel Combine; construction of ore storages and widening of individual drying and briquetting of ores at the Ufaleisk Nickel Works; introduction of the process of impoverishment of liquid converter slags in the electrofurnace at all of the works of the metal industry.

Twenty-five years ago we did not have domestic nickel and cobalt, while today we have a whole branch of industry producing nickel and cobalt, which is constantly growing and improving its techniques, thereby assuring the supply of the constantly increasing demand for these important metals in the national economy of the USSR.

The workers, engineers and technicians of the enterprises of the nickel-cobalt industry are successfully dealing with the problem of the supply of these metals.

On the twenty-fifth anniversary of the birth of the nickel industry we wish all of the workers of this branch creative success in solving the further problems of increasing the level of production.

(pp 7-11)

I. G. Torubarov, Central Planning Board of the Russian Soviet Federated Socialist Republic

<u>The nickel-cobalt industry in the period 1959-1965</u>

The decisions of the 20th meeting of the KPSS determine the direction and rate of the further development of nonferrous metallurgy for assuring the supply of nonferrous and rare metals to the more important branches of the national economy. Particular importance is attributed to the development of the nickel-cobalt industry.

The nickel-cobalt industry, created during the period of Soviet power, occupies today with respect to the production of nickel one of the first places in the world.

The increasing demands of the arts for nickel- and cobalt-containing materials possessing increased strength at high temperatures, resistance to corrosion, increased viscosity and plasticity, high electroresistance, acid-resistance and other important characteristics have determined the importance of nickel and cobalt in the national economy.

Nickel is mainly employed for the production of various nickel-alloyed alloys and steels, including rustless and refractory materials, and products thereof, and for the production of rolled nonferrous materials, mainly nickel and copper-nickel.

Nickel sulphate is employed in the electroindustry mainly for the production of iron-nickel alkaline storage batteries. Metallurgical nickel, sulphate and nickel protoxide are employed for the production of chemicals, reagents, catalysts, enamelware, etc.

The greatest employment (except for the storage-battery industry), is that of nickel-carbonyl powder for the production of metalloceramic products.

In recent years there has sharply increased the employment of cobalt in the production of series of steels and alloys, thanks to its high technical characteristics. Cobalt finds wide employment for the production of highspeed steels, alloys for machine construction and magnetic alloys for the radio industry.

The growing demand for nickel and cobalt determines the scale and rate of the production of these metals.

There is being planned the reconstruction and expansion of existing enterprises as well as the construction and operation of new nickel and cobalt enterprises. For this we have the necessary raw-material basis. The total development of the supplies of nickel-cobalt ores assures the work of the enterprises of the nickel-cobalt industry for several decades.

The increase in the supplies of ores is obtained mainly by the development of open mining.

It is planned to bring into production new nickel and cobalt deposits.

The ore basis of the Ufaleisk Works of the South-Ural-Nickel Combine is being expanded by the introduction of new and the expansion of the existing mines.

The ore basis of the Pechenga-Nickel is being greatly developed. The development of the supplies of sulphidic copper-nickel ores of this region is enabled by the expansion of the existing mine and the opening new large mines, including, as at Zhdanovsk, mines worked according to the open method. On the basis of the ores of the Zhdanovsk deposits there is planned the construction of a large concentration works (1).

The planned increase in the supplies of ores requires a considerable improvement in the technical level of the mining work, wider mechanization, increased productivity of the work; at the same time cost of production of the ores will be lowered.

At the open mines, besides better utilization of the existing mining equipments, it is planned to provide the mines with more powerful equipments and corresponding transport means: excavators with a bucket capacity of 4-6 cubic meters and draglines with a bucket capacity of 1.5-2 cubic meters, motor and electric locomotives with a coupled weight of 150 metric tons, large self-unloading cars with a capacity of 60 and 90 metric tons, dump trucks with a capacity of 25-40 metric tons.

The productivity of the excavators with a bucket capacity of 1 cubic meter is expected to reach 200,000 cubic meters per year.

At the development of the ore deposits worked according to the underground method there is planned the employment of high-output systems, wide utilization of highspeed perforators, powerful loading machines, large-capacity cars and more powerful excavators.

t the concentration works there must be solved the problem of improving the work of the grinding shops by improving the equipments and the introduction of hydrocyclones. In the flotation shops it is first all necessary to provide more flotomachines, and to introduce wear-resistant replacement-parts for the flotomachines and pumps. For increasing the extraction of the metals it is necessary to employ two- and three-stage grinding with intercyclic flotation, with employment of better flotoreagents and in a wider assortment.

In the near future there will have to be solved an important problem: formulation of effective methods for the enrichment of poor oxidic nickel ores.

A further increase in the output of the productions of the existing nickel works and their operation at a high technical level requires a considerable expansion and reconstruction of many of the works. This reconstruction will be carrried out mainly in the following directions: Introduction of more modern methods of caking fine ores and concentrates before melting; changing from shaft melting of the ores to melting in the electrofurnace in regions with a favorable electrobalance; improving the shaft melting of briquettes and agglomerates; lowering the losses of nickel and cobalt with the dust and discarded slag; introduction of new technological processes and modern apparatuses; complex processing of raw materials and obtaining new forms of production; incredsing the productivity of the work and lowering the costs of all forms of production.

In the accompanying figure there is shown the dynamics of the improvement in the indices of the metallurgical production of nickel.

At the South-Ural-Nickel Combine the development of the whole production is at present retarded by the absence of storage for the averaged ore and insufficient capacity of the agglomerating works. According to the planned reconstruction of the combine, which has already begun, there will be constructed large storage space for the averaged ore, with extensive mechanization of the loading-unloading work, as well as a agglomerating works with twice the area of the present caking machines. This gives the possibility of shaft melting on stably fluxed and sulphided agglomerates of a constant chemical composition. To a considerable extent there must be reconstructed the melting shop, with complete mechanizationand automation of the transport of the materials to the furnaces. The blower system will be strengthened, and the shaft furnaces will be converted for operating with high and closed charging; granulation of the slag will be replaced with hot dumping; the processing of the converter slag will occur in special electrofurnaces. There will also be expanded and reconstructed the following steps of the production of nickel and cobalt. There will be considerably reorganized the cobalt-sulphate shop, with removal from it of the sulphate and hydrate production of nickel to a special shop. There will be introduced new processes withemployment of oxygen, high pressure, deep vacuum, and apparatuses of continuous action.

Processing at metallurgical works of ores containing nickel and extraction of nickel (in the whole industry in % referred to 1956): (1) processing of ores; (2) extraction of nickel; (3) content of nickel in ores. (a) processing of ores; (b) content and extraction of nickel; (c) year

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As a result of the reconstruction of the works the extraction of nickel was increased from 60 to 75% and that of cobalt from 27.5 to 41% and the outputs of nickel and cobalt were considerably increased.

The development of the production of nickel in 1959-1965 at the Ufaleisk Nickel Works will be based mainly on expansion and reconstruction of the existing works.

According to the planned expansion of the Old-Ufaleisk Works there will be constructed closed storage space for the ore, and expanded the drying, melting and roasting shops. Substantially will be reconstructed the melting shop, where there will be installed one more shaft furnace, modernized the briquetting press, replaced the blowers with more powerful one, and at the sametime improved the dust-collecting system; the bessemerization will be carriedout in horizontal converters, and the impoverishment of the converter slags in electrofurnaces. The existing cobalt production will be reconstructed for enabling processing of new types of raw materials. All of this will enable increasing the quantity of ore processed and increasing the extraction of nickel by 3% and the extraction of cobalt (referred to the cobalt production) by 20.5%.

At the New-Ufaleisk Works it is planned to adopt a technological scheme of production based on the most modern processing of oxidic nickel ores and modern technological apparatuses.

At the Pechenga-Nickel and the North-Nickel Combine there is planned by 1965 a considerable increase in the output of nickel, cobalt and crude copper compared with 1956. The increased output of the production is assured by the expansion not only of the ore-concentrate economy but also of the production of both combines. At the Pechenga-Nickel Combine there will be installed on more large electrofurnace for melting ores and concentrates. By the end of the plan period the North-Nickel Combine will have changed over mainly to the processing of Zhdanovsk concentrate and Pechensk converter matte. The expansion of its melting shop contemplates the installation of onemore ore electrofurnace, and discontinuing in 1961 the melting of ores in shaft furnaces. There will be expanded and extensively reorganized the electrolysis of nickel, and constructed and taken into operation a new electrolysis shop. In correspondence with its increasing production the combine will expand some of its other shops and services. As a result of these measures, theintroduction of new technological processes and modernization of the equipment for extracting the metals the extraction of nickel at the works will be increased from 89 to 93%, that of cobalt from 46 to 57%, and that of copper from 90 to 93%.

An improvement in the technical level of the metallurgical production ofat the Norilsk Combine will be obtained by the employment of more modern technologies. In 1958-60 shaft melting will be replaced with melting in ore-thermal electrofurnaces of large capacity; the present technology of the production of cobalt will be changed: the converter slag impoverished in the electrofurnace and all of the cobalt will be sent into the converter matte for subsequent extraction. Some of the other operations will also be reorganized: flotation of the converter matte; roasting of the nickel concentrate; electromelting of nickel protoxide on anodes, and others; there will be introduced new technological processes for recovering accompanying metals. There are contemplated measures for increasing the output of metals and the complexity of processing of raw materials, for increasing the extraction of the metals in the finished production and lowering the cost of production. At the new nickel works there will be employed a more advanced scheme of processing of oxidic nickel ores than that employed at the Ural Nickel Works. According to this scheme the ore with the flux is subjected to agglomeration, and the fluxed agglomerate is melted with a reducer in the electrofurnace to poor ferronickel, which is blown in the converter to rich ferronickel. The scheme gives a high extraction of metals, and enables the employment of iron converter slag in ferrous metallurgy.

There has been formulated a somewhat more advanced scheme of processing, whose detailed investigation is now under way at institute and on pilot plants. If the scheme is found feasible, large nickel enterprises will be erected in the eastern part of the country.

Of great importance at the processing of nickel-cobalt ores is their complex utilization. In the available oxidic nickel ores the principal industrial component besides the nickel is the cobalt, and in the sulphidic ores also the copper. The complexity of the extraction of the cobalt and copper is determined incidentally with the extraction of the nickel at both the enrichment and the metallurgical processing of the raw material. A considerable part of the increased output of cobalt in the plan period will be obtained as a result of its increased extraction at the metallurgical processing; in comparison with 1956 the extraction of cobalt in 1965 will be increased 1.6 times.

In the deposits of various kinds of ferrous nickel ores, the iron is also of industrial importance. At the construction of the new nickel works it is intended to process the nickel and cobalt ores with incidental recovery of the iron.

In the sulphidic ores of the Zapolyar enterprise there are contained a number of valuable components - expensive and rare metals, which are extracted incidentally with the principal metals. By improvement of the existing and the introduction of new technological processes it is expected to increase the quantities of extracted valuable components and to increase their extraction from the raw material.

A great shortcoming in the work of the nickel-cobalt industry is the failure to utilize the sulphur in the departing sulphur gases. Large quantities of sulphur, occuring at the present time with sulphidic ores, or, at the special introduction at the melting of oxidic nickel ores, by sulphidation (with gypsum, pyrites) are let out of the converters and roasting furnaces into the air in the form of sulphur gas. The planned reconstruction contemplates the utilization of the sulphur at the works of the Pechenga-Nickel, North-Nickel, South-Ural-Nickel and Ufaleisk Combines, where there will be provided installations for recovering sulphuric acid or liquid sulphurous anhydride from the sulphur gases. At the Norilsk Combine there will be expanded the existing sulphuric-acid shop.

The utilization of the slags of metallurgical production for the production of building materials - wall blocks or bricks, rubble, slag blocks, slag wool, etc - is determined in each particular case by the local conditions and demand. It is planned to utilize the slag for this purpose at the South-Ural-Nickel and the North-Nickel Combine. In the planned reconstruction of the enterprises there is also being solved the problem of utilization of the heat of the liquid slag.

The development of the nickel-cobalt requires considerable capital outlays for the construction of new mines and works and the reconstruction of existing enterprises as well as for compensating the abandoned capacity of mining enterprises.

It is calculated that planned capital outlays for the nickel-cobalt industry for the whole plan period will lower the unit costs of production by approximately 2[illegible]% compared with the actual costs through 1958. At this ratethe productivity of th the work in 19[illegible] (referred to the individual industry groups) will be increased 1.5

and (referred to the industry as whole) 1.6 times, at a lowering of the costs of production of nickel by 2[illegible]% and of cobalt by 47%. Consequently the effectiveness of the capital outlays in the nickel-cobalt industry will be considerably increased.

Besides increasing the outputs of nickel and cobalt an important problem is the economizing of nickel and cobalt by replacing them as alloying additions with chromium, molybdenum and boron; by a wide adoption of steels and alloys without a content of nickel; by the exclusion of cobalt from less important alloys; by employment of plastics instead of nickel in various articles and fittings; by a wider employment of galvanizing, etc.

The Soviet Union possesses large known resources of nickel and cobalt. The considerable volume of geoprospecting planned for 1959-1965 will still further increase these known resources, thereby assuring further increase in the capacity of the nickel industry after 1965.

The reorganization of the management of industry and construction according to the decision of the Party and the Government has already given important results; thus the plan for the first quarter of 1958, was overfulfilled by all of the enterprises of the nickel-cobalt industry. In comparison with the first quarter of 1957 the volume of open mining was increased by 33%, the output of ores by 13.1%, the outputs of nickel and cobalt by 10% each.

The development of the production of nickel and cobalt will supply the growing demands of the national economy.

Footnotes

(1) Compare "Enrichment and agglomeration of ores of the northwest regions of the [illegible], [illegible], [illegible], pp [illegible].